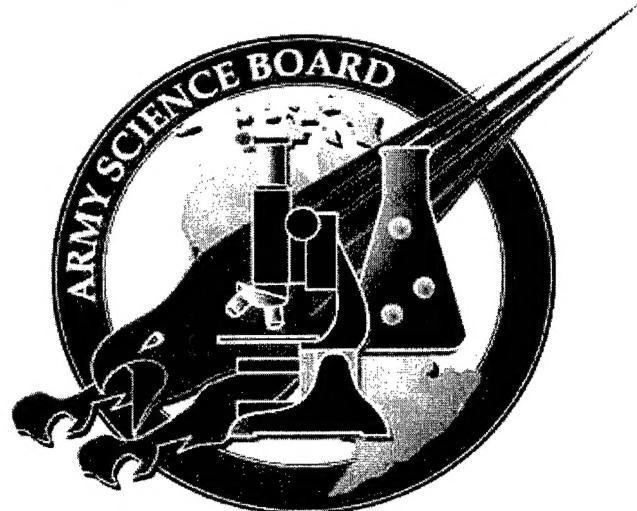


ARMY SCIENCE BOARD

FY2000 SUMMER STUDY

FINAL REPORT



20020528 052

DEPARTMENT OF THE ARMY
ASSISTANT SECRETARY OF THE ARMY
(ACQUISITION, LOGISTICS AND TECHNOLOGY)
WASHINGTON, D.C. 20310-0103

"TECHNICAL AND TACTICAL OPPORTUNITIES FOR REVOLUTIONARY ADVANCES IN RAPIDLY DEPLOYABLE JOINT GROUND FORCES IN THE 2015-2025 ERA"

VOLUME I EXECUTIVE SUMMARY REPORT

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CONFLICT OF INTEREST

Conflicts of interest did not become apparent as a result of the Panel's recommendations.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Hwy, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington D.C. 20503.			
1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED	
	April 2001	Army Science Board – FY2000 Summer Study	
4. TITLE AND SUBTITLE Technical and Tactical Opportunities for Revolutionary Advances in Rapidly Deployable Joint Ground Forces in the 2015-2025 Era -- Volume I - Executive Summary Report			5. FUNDING NUMBERS
			N/A
6. AUTHOR(S) Co-Chairs: Dr. Joseph V. Braddock, Dr. Marygail Brauner, LTG Paul Funk (USA, Ret.) ASB Subpanel Chairs: Mr. Ed Brady, Dr. Philip C. Dickinson, Dr. Robert E. Douglas, MG Charles F. Drenz (USA, Ret.), Dr. Harold F. O'Neil, Jr.; GEN Leon E. Salomon (USA, Ret.) ASB Panel Members: Dr. Frank H. Akers, Jr; Mr. Buddy G. Beck, Dr. John Blair, Dr. Gregory H. Canavan, Dr. Inderjit Chopra, Dr. David S.C. Chu, Mr. John Cittadino, Ms. Christine B. Davis, Mr. Francisco A. Figueroa, Mr. Carl B. Fischer, Mr. Jerome S. Gabig, Jr.; Dr. Lynne G. Gref, Dr. John F. Holzrichter, Dr. Anthony K. Hyder, Mr. Kalle R. Kontson, Dr. Michael D. Krause, Ms. Joanna T. Lau, Mr. Ray L. Leadabrand, Dr. Peter Lee, Ms. Susan G. Lowenstam, Mr. David R. Martinez, LTG John E. Miller (USA, Ret.), Dr. Reynaldo Morales, Dr. L. Warren Morrison, Dr. Samuel Musa, Dr. James A. Myer, Dr. Gary R. Nelson, Dr. Irene C. Peden, Mr. Srinivasan Rajagopal, Mr. John H. Reese, Dr. Joseph E. Rowe, Dr. W. James Sarjeant, Dr. Harry L. Tredennick, Dr. Annetta P. Watson, Dr. Gershon Weltman, Dr. Robert S. Ziernicki			
7. PERFORMING ORGANIZATION NAMES(ES) AND ADDRESS(ES)			8. PERFORMING ORGANIZATION REPORT NUMBER
EXECUTIVE SECRETARY Army Science Board SAAL-ASB, Suite 11500 2511 Jefferson Davis Highway Arlington, VA 22202-3911			N/A
9. SPONSORING/MONITORING AGENCY NAME(ES) AND ADDRESS(ES)			10. SPONSORING/MONITORING AGENCY REPORT NUMBER
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11. SUPPLEMENTARY NOTES N/A			
12A. DISTRIBUTION/AVAILABILITY STATEMENT Approved for Public Release; distribution is unlimited			12b. DISTRIBUTION CODE A
13. ABSTRACT (Maximum 200 words) The Army Science Board was tasked to seek revolutionary possibilities for improving deployability as well as effectiveness of future joint ground combat forces. The study focused on the possibilities inherent in the Future Combat System(FCS) and also considered enhancements possible through the Future Transport Rotorcraft (FTR). Study efforts were conducted by four major Panels analyzing: Operations, Information Dominance, Sustainment and Support, and Training. The study concludes: 1) the FCS concept is sound, but senior level attention is required to ensure technologies are ready for 2006 FCS EMD; and 2) Key technologies will significantly improve force projection and combat power.			
14. SUBJECT TERMS Future Combat System, FCS, Future Transport Rotorcraft, FTR, Global Information Grid, GIG, Infosphere, Embedded and Networked Training, Training Dominance, Ultra-Reliability, Sustainment, Operations			15. NUMBER OF PAGES 112
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THE PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT None

FY 2000 Summer Study Report Format

The FY 2000 Summer Study has been published in 5 volumes.

- **Volume I - Executive Summary**
- **Volume II - Operations Panel Report**
- **Volume III - Information Dominance Panel Report**
- **Volume IV - Support and Sustainment Panel Report**
- **Volume V - Training Dominance Panel Report**

If you received only the Executive Summary, the additional volumes may be reviewed and/or downloaded by visiting

<http://www.saalt.army.mil/sard-asb/> and clicking on “Studies.”

**Technical and Tactical Opportunities for Revolutionary
Advances in Rapidly Deployable Joint Ground Forces in the
2015-2025 Era**

Executive Summary Report

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**Introduction and Overview
Army Science Board Summer Study 2000**

**Technical and Tactical Opportunities for Revolutionary Advances
in Rapidly Deployable Joint Ground Forces in the 2015-2025 Era**

BACKGROUND

In Mid-December 1999 the Army Science Board (ASB) initiated the Study using an enabling, rather than a prescriptive, Terms of Reference (TOR). Study leadership formed four panels, which addressed improvements the Army wanted and the challenges that had to be met to achieve them. Panels included Joint and Reserve representation as well as participants from other Service advisory boards.

THE OBJECTIVE FORCE AND ITS DEVELOPMENT PROGRAM

The Study focuses on the future force, one that might be employed beginning in 2015 and possibly extending through 2025. It concentrates on the forces at the point of the spear, namely those at battalion and below. The Army is currently executing a joint program—the Future Combat System—with DARPA, to make decisions about the start of an engineering and manufacturing development (EMD) program in the 2005-2006 timeframe. The ASB's examination extends further out in time and embraces more technological capability than the Army-DARPA program. Its results, however, will be applied not only in that far term but also in the nearer time period covered by the current Army plans.

The Army is developing operation and organization concepts for its future force. These have matured and will continue to mature over time. This ASB study employs current TRADOC developments for the Objective Force.

In brief, the goal is for rapid power projection by air. Future forces will maneuver in the air and on the ground within the theater. They will have substantially improved survivability and lethality over today's forces and operate with a "red zone" of 10-12 km that is considerably larger than the 3-5 km envisioned in current doctrine for open terrain. In complex terrain (urban), the "red zone" would expand to as much as 1-1.5 km compared with today's tens to a few hundred meters. A large portion of the force's survivability derives from its ability to locate and engage the enemy first, employing robots and long-range fires. The force will control more space with less manpower and require only a small fraction of the consumables used by today's units. The combination of these improved force characteristics will give the United States the ability to deny an enemy "set" with conventional forces and create conditions to seize and hold the initiative and prosecute decisive operations. Supply and support infrastructure (division, corps, echelon above corps, etc.) will also be reduced to a third or less of today's.

APPROACH

The Study carries forward and builds upon prior ASB and Defense Science Board (DSB) studies. These dealt with the major challenges that limit the capabilities desired in the future. These challenges include:

- The unforgiving and very short close combat timelines in and near the close-combat “red zone”
- The limits of passive armor and momentum exchange protection
- The limitations on both sensing and communicating from the ground, close to the ground, or even with elevated moving platforms
- The limitations associated with DoD fleet airlift (fixed-wing and rotary) as well as commercial airlift
- Latency in the sensing-decision-action process within an echelon
- Latency implicit in multi echelon exchanges of information and orders.

POSSIBLE TECHNOLOGICAL INNOVATIONS

To achieve the desired force characteristics, the study posited promising technologies in its use. It did not address concepts of operation or organization.

The demand for rapid deployment by air limited vehicle weight. Thus the study considered what could be done in the range of 5 to 20 ton vehicles. Platform survivability derives from both improved passive armors for smaller caliber and man-portable weapons and improved engagement conditions, active protection systems, signature management, and the employment of robotics. The need for these capabilities implied a collaborative solution rather than the traditional platform-centric approach. The view of the study members is that clusters of available technologies provide the building blocks for the core elements of FCS. Key technologies cluster in the following areas:

- Tactical Infosphere
- 20-ton multipurpose vehicles
- Netfires
- Robotics
- Embedded and networked training
- Logistic efficiencies
- Future Tactical Rotocraft

Tactical Infosphere. Improvements in long-range engagement and situation awareness require an organic combat unit “infosphere” of C4ISR systems, which enable much improved offensive, defensive and survivability capabilities. Systems could include MTI/SAR/IFSAR radar, LIDAR, ELINT EO-IR including retroreflecting and UGS, etc. Both ISR and communications systems require elevated platforms that can “stare” and “perch,” as contrasted with fly-through platforms. Ongoing DARPA development of the robotic A-160 rotocraft, possibly smaller derivations, and ducted fan platforms offer these capabilities. The A-160 and possible smaller derivations are long-duration (up to 40 hours) robotic platforms. These could provide an organic presence yet be

maintained in the rear at a support base and perform missions without burdening the combat forces.

The operational concepts implied by these technologies represent a marked departure from the way today's forces are equipped, organized and operated. Currently, most warfighting information comes from sensors and information sources at echelons well above the combat units. Centralized theater assets, while they will provide valuable inputs for activities with longer time horizons, are judged not able to provide the fine-grained and time-urgent information needed for the combat unit fights.

Sensor technology is available for platforms to operate in open, broken, and forested terrain. Combinations, sometimes operating sequentially, will be needed to employ fairly reliable radar, ELINT and acoustic "blobology," growing ATR capability and follow-up, focused LADAR, EO-IR, hyperspectral, and UGS. Urban terrain, however, will require an expanded use of this family of sensors, particularly UGS.

Communications to provide the sensor-to-shooter connectivity and enable the massing of lower echelon effects will require substantial improvements over what the Army has today. A good starting point is a distributed, elevated communications system instead of today's ground based combat radio nets, using SINCGARS and EPLRS systems. Such a future system will be needed to support ISR, C2, robotic employment and training. The DARPA SUO-SAS and its clear and efficient spectrum usage are part of the technology solution to get more bandwidth while achieving covertness.

The commercial sector has important building blocks to offer. These include routers, lower cost electronically steerable antennas, wide-band transceivers, and network managers. Many (all?) vehicles could carry such components, providing an embedded communications system and obviating the need for the traditional overlay with its additional platforms and soldiers. The ISR system has extensive embedded communications in its actual components and query-reply devices such as DraFT (Digital Radio Frequency Tags), have multiple uses, and can provide Joint and Combined linkages. GPS robustness can and must be technologically assured. Pseudo-satellites are part of the solution.

20-ton Multipurpose Platforms. Strategic and tactical air mobility will require the lighter (5-20 ton) platforms. There are important breakpoints in both development and technology risk, and in cost as a function of the weights of the vehicles. The so-called sweet spot for technology and cost is 10 tons. At this weight, the entire commercial air fleet is available, and so is the entire DoD fleet, including much of its rotary wing complement. However, dramatically improved capabilities would result if a 20-ton platform can be lifted as well, with either pure rotary wing or tilt-rotor VTOLs. Commercial air freighters with applique flooring can transport 20 ton vehicles.

Netfires. The Army has a robust extended-range weapons program. Netfires offers a responsive "rockets-in-a-box" innovation to employ missiles. The effective use of extended-range weapons demands low latency for decision making and engagement processes. Loitering missiles offer the possibility of achieving such performance. Command Post of the Future (CPOF) technologies

and processes demonstrate significant promise for meeting Army decision-making and engagement process needs.

L lethality. The Army has a substantial and promising set of guided projectiles, missiles, and artillery submunitions to meet objective force needs. Choices will be driven by concept and affordability.

R obots. Technology will be available for the Army's planned development for either a follower or an assisted path robot with information derived from the organic ISR system. Autonomous robots were judged to unavailable for 2006 EMD but would be available for 2015-2025 insertions.

E mbedded and N etworked T raining. Training innovations offer improvements comparable to those of new battlefield technologies. History shows that world-class training improves performance by as much as an order of magnitude. When units are similarly equipped, the better trained one wins. As potential antagonists take advantage of readily available commercial technology, the training advantage assumes even more importance. This study recommends embedding the training in the organic ISR and C2 systems so it is seamless, available and used by units at home stations as well as by those that are deployed. In addition, coupling to a modern distance learning program (not the current Army program) would enable most of the education required to be delivered at the units rather than in institutional schoolhouses. Major cost savings derive from doing this.

L ogistic efficiencies. Today's forces use large amounts of consumables, requiring large support infrastructures. Reducing the average weight of the vehicle by a factor of three reduces fuel consumption by a factor of three. Using hybrid electric propulsion with diesel as the primary fuel will improve efficiencies by 50% over the factor of three provided by the reduction in vehicle weight. It will also allow the Army to eliminate generators and enable a move to a distributed command post concept, eliminating tactical operations centers that are large, easily found and vulnerable. Other possibilities for reducing the amount of consumables that have to be brought into theater include extracting water from the exhaust of diesel. Fuel cells, which might provide electric power and water, are possible in the far future, but these are not available for the 2005-2006 EMD

F uture T actical Rоторcraft. Technology for a 20-ton lifter (at 4,000 ft. altitude, 95° F day) is becoming available. This objective force building block adds multiple capabilities for austere force insertion, agile air sustainment, operational and tactical mobility and direct ship unloading which frees the Army and Marines from depending on air and sea ports.

LARGER SCALE IMPLICATIONS

The technologies described would endow the Objective Force with truly revolutionary capabilities. A substantial force having brigade-like technical capabilities and controlling substantial areas could be fielded in the total weight range of 3,000 to 6,000 tons. More traditionally designed forces are heavier by a factor of two or three. It will be possible to insert these lighter forces in a period of four to six hours using the FTR.

A major attribute of the Objective Force lies in its ability to mass effects, not forces. Massing could be done for fires, ISR, logistics, mobility, and for other domains, such as communications. To realize these advantages, the Army must pay particular attention to eliminating or achieving major reductions in C4ISR vulnerabilities. Efficiently and effectively employed, such capabilities will make for the nation its most precise execution force which is at the same time highly agile and survivable.

OVERARCHING RECOMMENDATIONS

The challenge for the Army (and DARPA at the front end of the FCS program) is to develop technologies and building blocks and integrate them effectively in a system of systems context. The integration must start now and expand as EMD ensues. To ensure the achievement of the desired collaborative force characteristics, two sets of overarching recommendations are made in addition to those put forward in the individual technology assessment and innovation sections.

Recommendations to assure the success of the DARPA-Army FCS program:

- Conduct frequent high-level technology reviews to ensure continuing success
- Develop initial virtual, distributed, man-in-loop emulation/simulation now
- Establish, under the AAE, an FCS C4ISR system architect / system engineer, and a “red team” now
- Create an integrating/proponency mechanism to address FTR now

Recommendations that can help ensure successful fielding of FCS:

- Employ a real-world, ongoing acquisition program as a test case to structure operation and sustainment cost reductions through a learn by doing approach
- Secretary of the Army and Chief of Staff of the Army should consider:
 - Having one message for many messengers
 - Creating a super program
 - Establishing a super systems engineer is required
 - Creating a long-term, expanded relationship with DARPA

Finally, the initial FCS concept and technology combination is sound. There are no “show-stoppers.” The key technology building blocks for the core elements can be ready for a 2005-2006 EMD. However, close operator-developer cooperation is needed now, and frequent senior level involvement is required to ensure success.

It is the judgment of the ASB that the Army should be able to achieve first unit equipped goal in 2010 for all core elements. Some elements (C4ISR, Netfires, A-160, CE Active Protection, Hybrid Propulsion) could be fielded by 2008 or sooner.

FY2000 ASB Summer Study

Technical and Tactical Opportunities for Revolutionary Advances in Rapidly Deployable Joint Ground Forces in the 2015-2025 Era

A prominent author from Nigeria named Chinua Achebe describes great undertakings and great civilizations in part by saying that they need three kinds of people: drum beaters, warriors, and storytellers. The drum beaters announce the great causes, the warriors achieve them, and the storytellers carry the accounts of those causes from generation to generation. In this briefing, we play the role of drum beaters and storytellers who are striving to help the warriors.

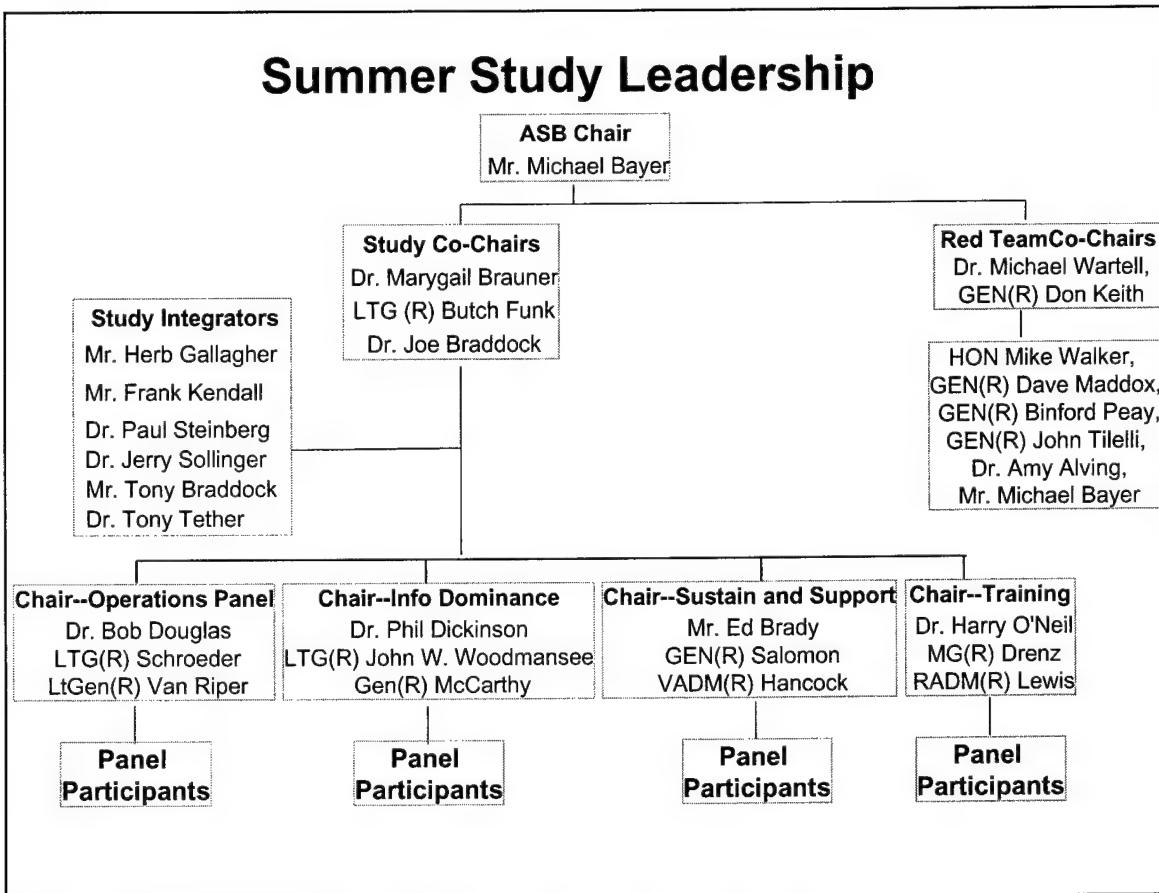
Study Sponsors

<u>Sponsor</u>	<u>Position</u>
• GEN John M. Keane	• Vice Chief of Staff, Army
• GEN John N. Abrams	• CG, U.S. Training and Doctrine Command
• GEN John G. Coburn	• CG, Army Materiel Command
• LTG John Costello	• CG, Army Space and Missile Defense Command
• LTG Paul J. Kern	• MILDEP to the ASA for Acquisition, Logistics & Technology
• LTG Randall L. Rigby, Jr.	• Training and Doctrine Command
• MG Charles C. Cannon	• Acting DCSLOG

In December of 1999, the Army Science Board initiated this study to address the possibility for revolutionary advances in rapidly deployable joint ground forces in the era 2015 to 2025. The sponsors shown above were involved in one way or the other in this undertaking.

At about the same time, the Army and DARPA (Defense Advanced Research Projects Agency) were initiating a program called "The Future Combat System" (FCS), which would provide capabilities to the Army in a somewhat earlier time frame. The FCS initiative was initiated by, and is still led by, LTG Paul J. Kern (MILDEP to ASA-ALT) and Dr. Frank Fernandez, the director of DARPA.

Summer Study Leadership



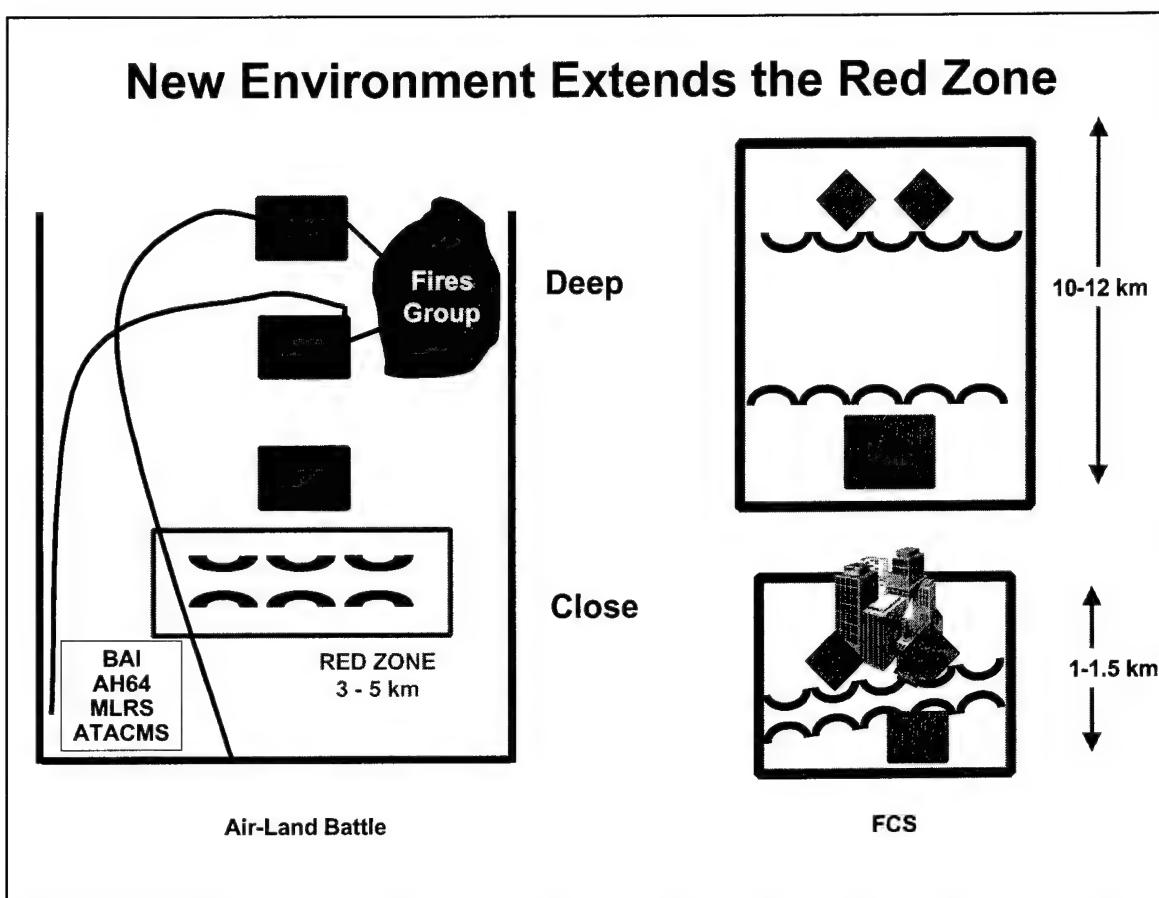
This study was led by members of the Army Science Board (ASB)--scientists, engineers, technologists, academics and operational experts who volunteer their expertise and time. Each of the four panels was co-chaired by a civilian scientist, a retired Army general officer, and a retired general officer from either the Air Force, Navy, or Marines. In addition to the participation of ASB members, the panels also had participation from industry experts and members of the National Guard and Reserve components. Separate reports from each of the panels are available and may be obtained through the Army Science Board at telephone (703) 604-7461, or www.sarda.army.mil/sard-asb/

Agenda

- **Background on ASB study**
- **Desired future Army capabilities and Army modernization**
- **Panel reports**
- **Summary**

This briefing is composed of four parts. The background has already been presented. This next section describes the capabilities the Army desires to deal with future threats and the Army's program to modernize its equipment to meet the future threat.

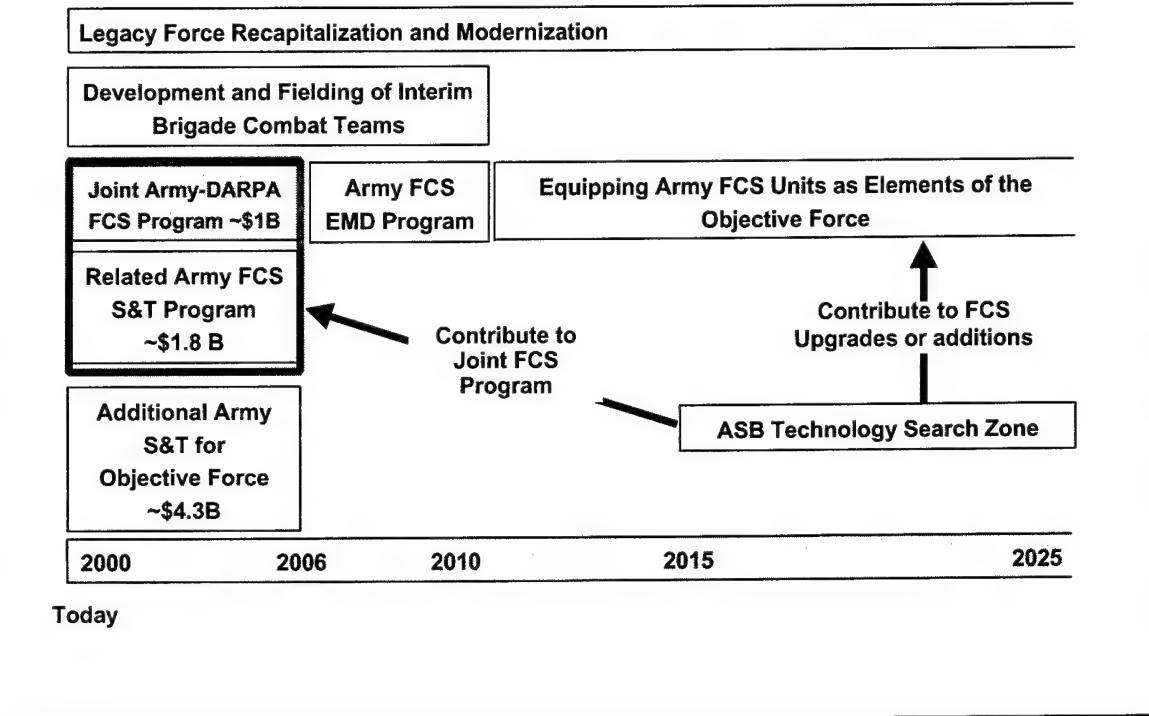
New Environment Extends the Red Zone



We begin by looking in the past and to the future. This chart presents background information in the sense that it compares older capabilities the Army has with the newer ones it is seeking.¹ The “red zone” (or zone of close combat) in the Air-Land battle extended from about 3 to 5 kilometers, and all the Army’s emphasis went into fighting outnumbered and winning. The right side of the chart shows what we are reaching for, although specifics can change with time. In the future, the red zone expands to 10 to 12 km (could be larger or smaller in the future) in open and rolling terrain and from tens or maybe a few hundreds of meters to 1 or 1-1/2 kilometers in very complex terrain. Of course, the operating principles that attend these expanded zones are still evolving.

¹ This chart is based on TRADOC documents

Army Modernization Program



What is the program to get there? This slide depicts the Army's modernization program and calls special attention to an element of that program. This slide also places this Army Science Board study in the context of the Army modernization program, which involves all of the Army, including recapitalization and modernization of the Legacy Force that won the Cold War and Desert Storm. The development and fielding of medium brigades includes an ongoing Joint and Army S&T initiative intended to develop an Army future combat system of systems. This initiative leads to an EMD program for that system, and ultimately the equipping of the objective force. The funding for this is about three billion dollars; one billion in the joint Army-DARPA program, and roughly two billion in a separate but tightly coupled Army S&T program. The full objective force modernization is being backed by an additional \$4.3 billion. The expectation is that the Objective Force will unfold over the next 20 to 25 years, with a fairly early start, about 2008 to 2010.

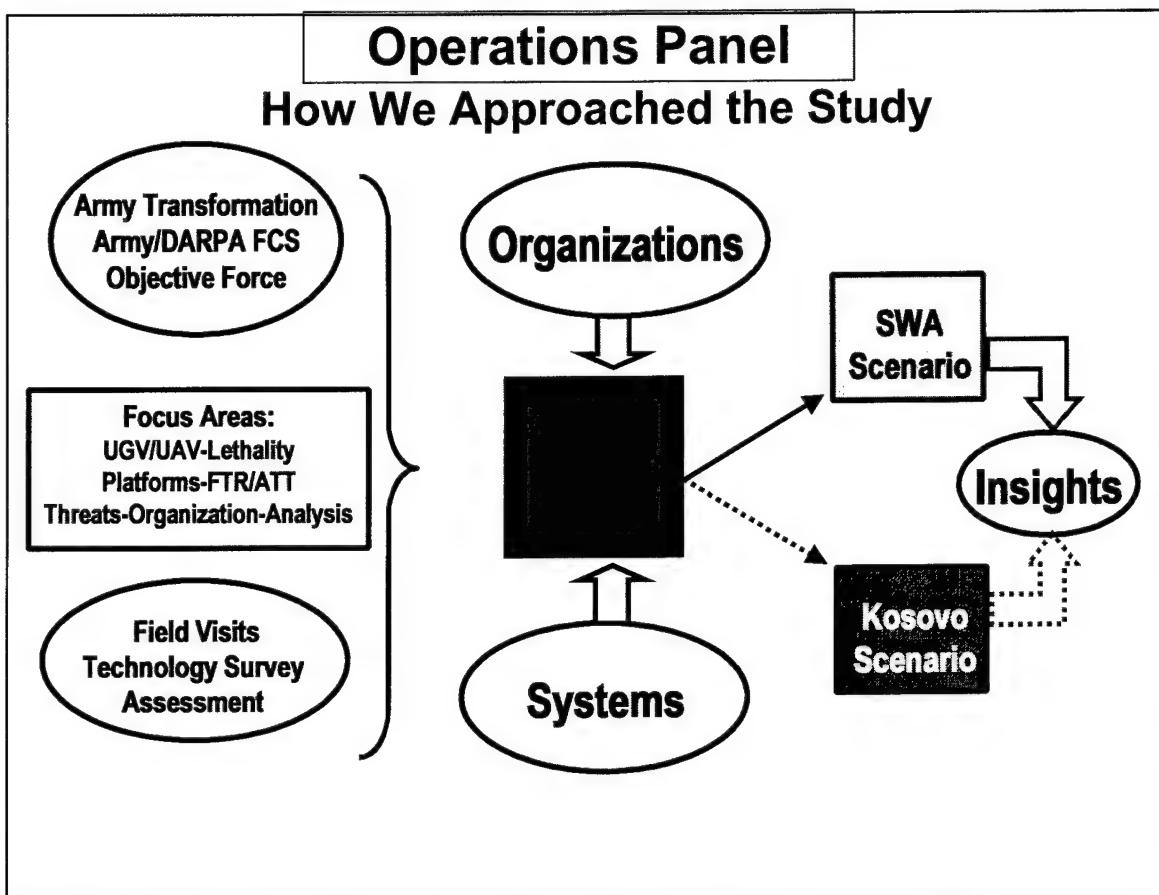
This Army Science Board study found technologies that could become available and support FCS engineering and manufacturing development beginning in FY06, as well as technologies that would contribute to further FCS upgrades and other programs.

We call special attention to the joint Army-DARPA FCS program. TRADOC is refining the CONOPS for that program, and that process will continue. Four industry teams are competing to join CONOPS with technology and underwrite the concepts that were discussed earlier in general terms. The FCS program not only contains exploration into CONOPS and technology, it also includes a risk reduction-maturation component dealing with the following: manned and robotic ground platforms, manned and robotic air platforms, net fires (sometimes called "rockets in a box"), a series of command control and communications initiatives, and sensors. Finally, there is a safety net of "government run experiments" which are intended to identify and investigate some of the clever ideas that show promise for inclusion in the FCS program.

Agenda

- **Background on ASB study**
- **Desired future Army capabilities and Army modernization**
- **Panel reports**
 - Operations
 - Information Dominance
 - Sustainment
 - Training
- **Summary**

To carry out our study, we organized ourselves into the four panels—operations, information dominance, sustainment, and training. The next section of this briefing will discuss the results of the four panels.



Based on the key issues and focus areas provided in the ASB terms of reference (TOR), the operations team started with a review of key Army warfighting concepts, the Army Transformation Strategy and major Army and DoD program including the DARPA / Army Future Combat System (FCS) program. A series of site visits to key installations and agencies were made to collect additional details and information on future science and technology initiatives and opportunities. Notional organizational designs were developed to allow supporting analytical assessments of benefits and trade-offs for emerging science and technology options. Future system possibilities were defined as representative examples available for the force in the 2015 to 2025 time frame. The notional force was then constructed to evaluate various force, systems and technologies issues relative to the overall force objectives and constraints.

Two scenarios (South West Asia and Kosovo) were used to get insights relative to the merits / challenges of selected technology options in different environments. A “system of systems” approach to the force provided a wide range of potential future systems and employment strategies. Insights used to develop overall team recommendations were supplemented by additional briefings and discussions from subject matter experts from government, industry and academia organizations.

Operations Analysis Involved Two Force Structures

- **The Fort Knox force**
 - 4 companies per battalion- 2 infantry, 2 fighter (more AT vehicles)
 - Organic
 - UAV
 - Net fires
 - Recon
 - Brigade slice of AD, artillery, support, signal, engineer, etc
 - Division slice
 - Some 10 ton vehicles
- **Medium Force**
 - 3 task organized maneuver battalions in light armored vehicles
 - Aviation battalion with Apache and Comanche
 - Advanced artillery battalion
 - Division slice elements (AD, engineer, military intelligence, etc.)

A number of real and possible organizations were examined. The spectrum included: a) the force XXI heavy brigade; b) a medium equipped with midterm technology; and c) a number of possible future brigades. Including sustainment, these organizations weighed 33,000 tons, 11,000 tons, and 3,000 to 6,000 tons, respectively.

Ft Knox Based Structure - Organizational Concept

This organization features four company combined arms teams that have three platoons of six vehicles, each containing both the infantry fighting vehicle and the anti-tank variants of the FCS.

There are 36 infantry squads with fighting vehicles and 36 anti-tank vehicles in each battalion.

The fighting vehicles are 20 ton FCS variants with composite armor and enhanced protective suites. The infantry fighting vehicle carries the infantry squad and mounts a tank killing direct fire rocket system. The anti-tank fighting vehicle has a two man crew and has a weapon capable of LOS and BLOS kills.

Each company team includes two tubes of 120mm mortar.

Additional fire support is provided by four net fires systems, each consisting of 30 rockets in a box capable of firing to 20 km range.

Reconnaissance troop employs multiple UAVs and UGVs to bring enhanced situational awareness to the commander.

The battalion weighs out at approximately 1800 tons with only the 20 ton variant of the FCS.

Operational Concept

The Battalion Commander employs this force as a combined arms team.

He depends on assured networked communications and excellent situational awareness from his organic means (UAVs and UGVs) as well as that provided by his parent headquarters.

His enhanced situational awareness allows him to engage the enemy force at long range and destroy the majority of threat forces before they close to disadvantageous range.

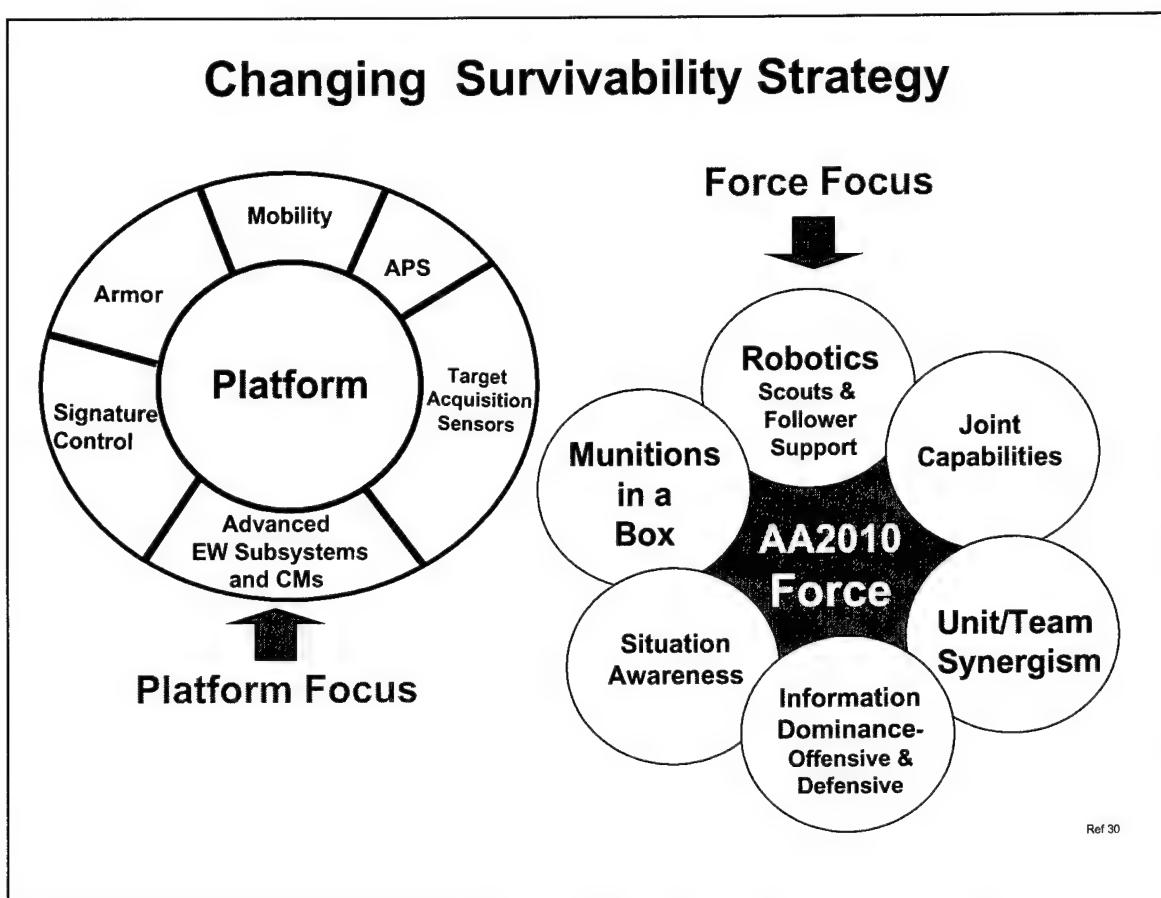
The primary killing systems will be AFSS and precision guided mortars for the destruction of the enemy well beyond line of sight.

At closer ranges, the LOS and BLOS systems carried on the fighting vehicles become decisive.

Mid-term Medium Brigade Organization and Operational Concept

The organization and operational concept are those now being finalized by TRADOC.

Changing Survivability Strategy



This chart depicts the changing survivability strategy. Prior (AA2010) and current (objective force) design studies have developed a multifaceted approach to survivability which includes a “system of systems” or total force trade assessments (to include platforms) as contrasted with the traditional “platform alone” focus of the past. The major difference lies in tradeoffs in crew size, protected volume and levels of passive protection. Much work remains to be done to realize the desired levels of strategic and theater air-mech mobility along with adequate survivability, lethality and endurance. One of the most promising new dimensions for improvement is in the area of robotics. While these are currently thought of in the context of Battle Force design, when successful, these unmanned systems/capabilities would expand the control and engagement space of Army XXI units as well.

Force survivability involves complex trades between several technology and capability areas. Survivability can be considered from two distinct perspectives – platform survivability and the capability of the overall force to avoid or minimize the impact of enemy attack. Examples of platform/system survivability features are shown on the left side of the chart. The objective force and legacy forces will exploit a balance of these emerging survivability technologies including active protection, signature

control, electronic countermeasures, platform mobility and lightweight armor protection. The ability of the platform to dominate an engagement while avoiding detection (e.g. exploit beyond-line-of-sight (BLOS) weapons) will also play a major role in survivability.

Survivability of the force will often include many complementary capabilities that provide substantial synergism to the force. Tactically integrating these capabilities can provide overmatching agility and freedom to maneuver. The ability to dominate battle space and control OPTEMPO will deny the enemy the option to execute his battle plan--posturing the enemy forces for defeat. For example, robotic (air or ground) vehicles in a scout role operating in conjunction with manned platforms and unmanned weapons follower vehicle, can facilitate precise BLOS kills at extended ranges, thus reducing manned platform exposure to threats. Joint capabilities, situation awareness, information dominance and teamwork are all major factors in force survivability.

In addition to these individual and differently provided capabilities, the network-collaborative massing of effects will provide quantum improvements in force protection, lethality, and OPTEMPO.

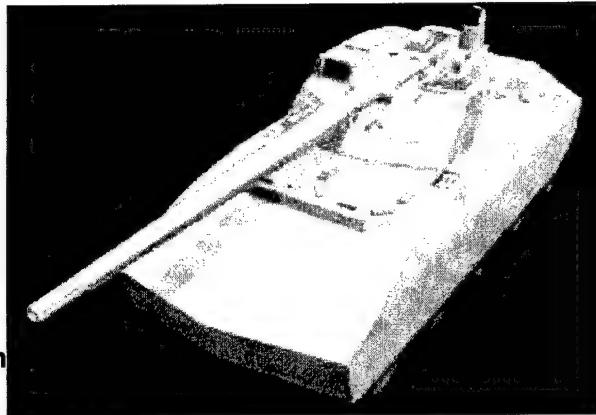
FCS (AT)

System Description

- 20 ton vehicle
- Crew of 2

Key Capabilities

- Lethality
 - Direct and indirect fire ETC cannon
 - KE overmatch T-90+
 - TERM with ~ 15 km range
 - Hyper-spectral sensors
- Survivability
 - Netted situational awareness
 - Signature management
 - Active Protection System (APS)
 - Passive (EM, ceramic and smart arm
- Mobility
 - Hybrid electric
 - High speed cross country
 - Dash/silent operation
 - Precision air insertion



The FCS Anti-Tank variant is a 20-ton vehicle with a 2-man crew and a direct fire ETC weapon capable of beyond-line-of-sight fires with the Tank Extended Range Munition (TERM) round. The gun elevates up to 60 degrees to enable precision fires at elevated targets in urban environments with programmable levels of lethality.

Survivability is enabled by enhanced situational understanding and long-range fires to avoid close combat with enemy tanks, signature management to avoid or delay detection, active protection against tank-fired and larger missile CE munitions, and passive armor to defeat all lesser threats.

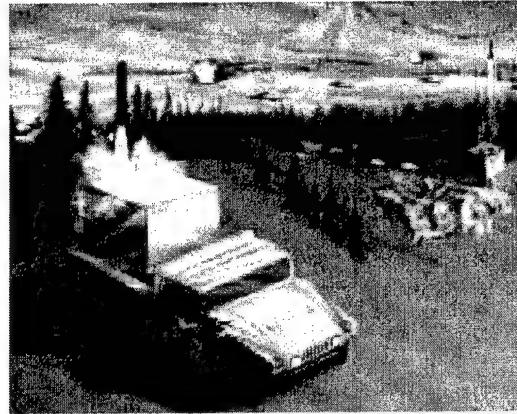
Ground mobility is enabled by a fuel-efficient hybrid-electric drive system. At 20-tons, the vehicle can be inserted precisely via parasail, landed by C-17 and C-130 and vertically inserted and redeployed by the future tactical rotorcraft. Commercial air freighters can also carry such vehicles directly to a theater when conditions are benign or to an Intermediate Staging Base (ISB)² for transfer to the theater via C-130, C-17 and/or FTR (Future Transport Rotorcraft).

² The ISB is a stage-to-fight area not a support base.

FCS (Net Fires) (formerly AFSS)

System Description

- ‘Munitions in a box’
- Could be carried by 10T vehicle or towed by robotic re-supply
- ~ 30 munitions
 - 20-40 km precision attack munitions (PAM)
 - 30 minute/200 km loitering munitions
 - Programmable warhead based on target type



Key Features

- Fully autonomous
 - Receives fire commands through comm network
 - Computes firing solution on board
- Box very cheap – throwaway?

The DARPA Net Fires (formerly the Advanced Fire Support System (AFSS)) program offers a method of autonomously delivering precision, long-range indirect fires. The “Rockets-in-a-Box” can be a stationary element, placed in the back of a HMMWV (as shown on the slide) or carried by the FCS weapon carrier shown on the previous one. Rocket boxes can be resupplied with a robotic “mule.”

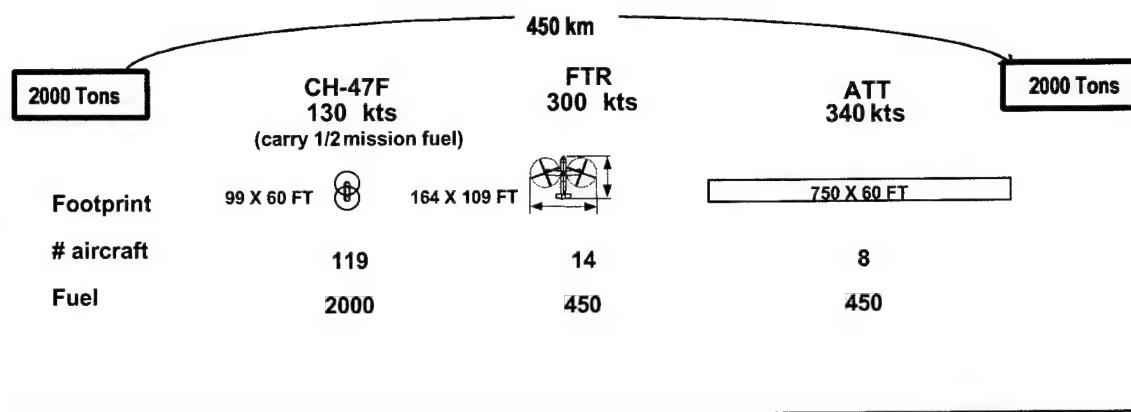
Warhead options include precision attack and long-range loitering munitions, both programmable to handle different types of targets.

The weapon system can be controlled remotely, and the launch mechanism (the box) can be designed to be a throwaway.

At least two missile types (precision attack and loitering attack) are being developed. Net Fires could also provide the carrier/dispenser means for inserting UGVs and related craft and expendable UAVs.

FTR Offers Revolutionary Operational and Logistic Advantages with FCS

- Deep, vertical envelopment with heavy force capability (ATWG 2000)
- Agile, intra-theater repositioning (ATWG 2000)
- Prevent enemy set
- Forced entry
- Synchronized attack of multiple centers of gravity
- Self-deployable
- By-pass air/sea ports
- Logistics over the shore
- Vertical lift/expansion of C-130 payloads



The Fort Knox designed Objective Force Brigade requires a 500 ton pulse of resupply every three days. The analysis shown here assumes the Brigade will be located 450 km from its supply source and re-supplied exclusively by air using either the CH-47F, the Future Tactical Rotorcraft (FTR) or the Advanced Tactical Transport (ATT). Each of these aircraft is assumed to fly a total of twelve flight hours per day. The FTR lifts 20 tons of payload and cruises at 300 knots, while the ATT carries 30 tons at 340 knots. Both of these aircraft can complete a resupply sortie without refueling. The CH-47F flies at 130 knots and must carry 2.64 tons of extra fuel for the flight back from the brigade, thereby reducing its payload to 5.26 tons.

With these payloads, the FTR requires 25 sorties, the ATT 17 sorties and the CH-47F 95 sorties to complete the mission. This implies that the logistics footprint for one landing zone or runway to support the brigade must accommodate almost four times the number of CH-47F's versus FTR's. The ATT will require a runway of 750 feet by 60 feet and a wing clearance lane of approximately 200 feet. The rotor/propeller disk loading determines the velocity of the downwash on the unprepared surface of the landing zone. The CH-47F has a moderate disk loading of 8.5 pounds per square inch, while the FTR may have a higher disk loading and thus produce more dust and create an uncomfortable working area.

under the hovering aircraft to manage sling loads. The ATT downwash will probably be greater than that for the FTR with the wing at a 45 degree angle as the ATT lands and takes off, although it is not clear how large the downwash for either would be.

In comparing the productivity of the three aircraft, the analysis illustrates that 32 CH-47F's are required for the mission versus 9 FTR's and 6 ATT's. The CH-47F's will fly 356 flight hours and burn 502 tons of fuel, while the FTR consumes 113 tons of fuel flying 41 hours. The ATT will consume 114 tons of fuel in the 24 flight hours it takes to complete the mission. The higher cruise speeds and greater payloads of the FTR and ATT enormously increase their productivity in comparison to the CH-47F and substantially reduce their aircraft fleet costs to complete the mission. At a unit fly-away-cost of \$25 million, the CH-47F fleet required for the resupply mission will cost \$1.5 billion. The FTR fleet will cost \$570 million for 9 aircraft at \$64 million each and the ATT fleet of eight aircraft will cost \$437 million at \$110 million each.

The primary insight from this simple analysis is that the productivity of an aircraft to perform a certain mission is much more important than just unit flyaway cost. The FTR is a substantially more effective vehicle for resupply at this distance than the CH-47F in terms of both fleet cost and the fuel used to accomplish the mission. The ATT is even more efficient than the FTR, but the ATT cannot land and takeoff vertically.

The FTR, particularly the faster tilt rotor version, underwrites multifaceted and revolutionary capabilities not now present in the joint force. The FTR has the greatest austere entry possibilities; it can unload ships, obviate the need for developed parts or "lota" capabilities; can resupply naval forces at sea and self deploy worldwide.

Major Insights from Analyses

- **Getting there early has significant benefits**
 - Must consider weight of sustainment force
 - Must include all necessary capabilities (e.g. Division slice)
- **Once ships arrive, they beat aircraft in strategic lift capability**
- **Getting into multiple unpredictable locations has value**
- **Killing before direct fire battle has major benefits including survivability**
- **Timely knowledge is key to this force and allows killing at range**
- **Killing at range requires resolution of latency issue**
- **Killing quickly has value**
- **A network centric collaborative force requires exquisite comms and large bandwidth**
- **Deployment time and lift requirements depend upon reduced consumption**

Getting to the fight early allows significant advantages to Blue, but we must not underestimate the weight and cube of the sustainment force and the various slice units that must arrive with, or very soon after, the FCS force.

Once the sea lift begins to arrive in theater, the amount of materiel that can arrive by ship far exceeds what can be strategically lifted by air.

Positional advantage can be achieved by insertions of forces into multiple unpredictable locations by not being tied to APODs and SPODs.

Killing the enemy at long range before the direct fire battle is joined has major benefits in survivability for the FCS force.

Very good situational awareness is crucial to allowing this killing at long range.

Future force technical capabilities, leader development, and combined arms training must resolve the latency issue of information transmission and decision making if the situational awareness is to be current.

Killing the enemy quickly and simultaneously has great benefits in survivability.

We must possess exquisite communications and bandwidth to make the network centric collaborative force work.

Deployment time and lift requirements depend upon reduced consumption.

Summary of Observations

- Overhead assets, even in 2015-2020, will likely be insufficient for situational understanding**
- Application of organic tactical sensors underwrite truly effective remote targeting and timely maneuver**
- Flexible air insertion helps to complete the balance between strategic, operational, and tactical maneuver**
- In combination, these new capabilities can provide the Army and Marines with the means to deny enemy “set”, seize and maintain the initiative and provide CINCs the circumstances to use joint forces most effectively**
 - Current design and analysis tools must be improved/expanded now**

The Kosovo-Scenario FCS force-simulation study resulted in several key observations:

An enemy who relies on cover, concealment, deception, intermingling, and dispersion will be impossible to monitor from overhead assets.

Organic ground sensors and overhead assets can find the enemy, but latency and potential collateral damage require organic sensor-shooter choices.

The FCS Force, even with a wide range of advanced technologies, requires non-traditional doctrine and tactics.

Flexible air insertion has the greatest promise of the technology and tactical alternatives, but also carries the greatest risk. Operational maneuver puts the enemy on the defensive, but survivability of the airlifters makes development of multi-spectral protection systems a high priority.³

The SWA scenario simulation showed dramatic performance improvements in all measures considered in comparing objective and legacy forces in combat in open and rolling terrain.

A final observation--CASTFOREM and JANUS by themselves will provide only limited design, assessment, and tradeoff capabilities. Since C4ISR capabilities are central to virtually all aspects of force

³We have assumed suppression of enemy forces that could be in the immediate vicinity of landing zones.

improvements, as a minimum man-in-the-loop virtual (probably distributed) simulation/emulation is needed and needed now.

Objective Force EMD Capabilities & Technology Assessment

Core Capability	Technology	EMD Risk (Tech Readiness Level ≥7 by FY06)		
		Required	Technology	Programmatic
Survivability	Composite Armor (Med CAL>30mm)	✓	Green	Green
	EM & Smart Armor		Yellow	Yellow
	Active Protection System - CE	✓	Yellow	Yellow
	Active Protection System – KE	✓	Yellow	Yellow
Lethality	Electro-Thermal-Chemical	✓	Green	Green
	Tank Extended Range Munition	✓	Green	Yellow
	Compact Kinetic Energy Missile			Green
	Precision Guided Mortar Munition		Yellow	
	Net Fires- Precision Attack Munition	✓	Green	Green
	Net Fires- Loitering Attack Munition		Yellow	Green
	MSTAR Guided/ER	✓	Green	
	DE/HPM Counter Sensor-Soft-Kill		Yellow	Yellow
	MPIM		Green	
Robotics	UAV Linked to FCS, RAH-66, + Reachback.	✓	Green	Yellow
	Semi-Autonomous UGV (Engineer, EOD, NBC, Logistics and Indirect Fire Functions	✓	Yellow	Yellow
	UGV (Direct Fires, RSTA/BDA)			Yellow
Tactical Mobility/Lift	Future Transport Rotorcraft (FTR)		Yellow	

Building on the 1999 ASB Summer Study, several high priority technologies were identified as significantly contributing to the Objective Force Capabilities listed. The required core capabilities for the initial FCS force, i.e. building blocks that should be fielded and upgraded in an evolutionary manner as the other identified technologies become available, are marked by a check. Thus we identified technologies which must be demonstrated to at least a technology readiness level of 7, in time to support a successful FY2006 EMD decision. The other technologies listed will mature after than the start of FCS EMD. These still deserve support because they: (1) could be available for a FUE; or (2) will so greatly increase objective force responsiveness, deployability, agility, versatility, lethality, survivability and/or sustainability, that they should be developed and fielded as soon as it is feasible and affordable. Examples include FTR, autonomous unmanned ground vehicles, etc.

The ‘Technology’ column contains an assessment of the technical risk for the technology assuming an EMD start of 2006. Technology risk categories are: Green - Low, Yellow - Moderate and Red - High. The following are high technical risks:

- Compact kinetic energy missile (CKEM) – unproven high specific impulse with low vulnerability propellant
- Directed energy/high power microwave counter sensor-soft kill – engineering scaling
- Autonomous UGV – Sensor fusion, signal processing and software for autonomy

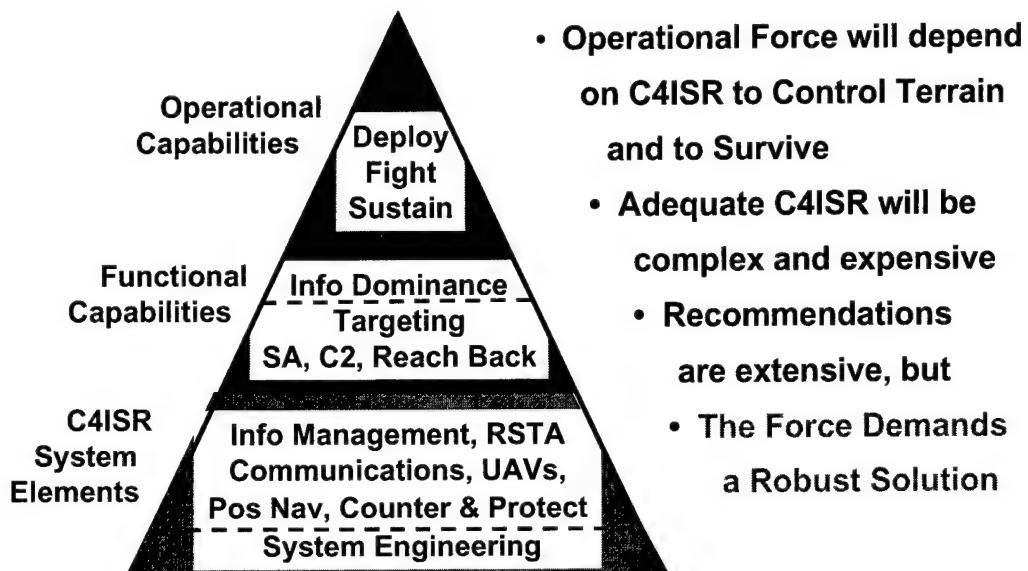
Programmatic risk assessments refer to the funding and schedule risk of the current funded army program: Green - Funding and schedule are adequate to achieve TRL of 7 by FY2006 EMD start; Yellow – Moderate risk due to inadequate funding and/or schedule; Red – unacceptable schedule &/or funding to get to TRL 7 by FY2006 EMD start. The following are high program risk:

- Multi-purpose individual munition (MPIM) - Procurement unfunded
- Precision guided mortar munition (PGMM) - No funded transition and ATD stretched
- MSTAR guided , extended range 270mm missile – MSTAR killed
- Ten ton (10T) vehicle – no funded program

The FTR represents a unique set of challenges and an enormous opportunity. Getting the correct program started and limiting the number of alternative technologies now is crucial. The Chief of Staff and Commandant should form a task force to formulate an agreed minimum set of requirements, particularly speed, lift, empty weight fraction and self deployment. Reliability, availability & maintainability must be established as a requirement now.

Information Dominance Panel

C4ISR in the Objective Force



Ultimately, a C4ISR structure must support the objective force's ability to deploy, fight, maneuver, and sustain. Underlying these operational capabilities are supporting functional capabilities that include information dominance, targeting, Situational Awareness (SA), Command and Control (C2), and reachback. Information dominance is an integration. Targeting is the process which supports determining potential target sets, recognizing and tracking them on the battlefield, matching firing systems with targets, delivering munitions and assessing the results. Situational Awareness (SA) is the integration of friendly and enemy dispositions, force status, and environmental factors such as weather, terrain, and civilian population. Command and Control (C2) refers to those capabilities, which support decision-making, leading, and control of the force. Reach back refers to those processes that support reaching to assets outside the theater or in sanctuary that can directly support operations inside theater.

Underlying these functional capabilities are the technical systems, which enable C4ISR. These systems have been subdivided to facilitate analysis of each component. They include Communications, Reconnaissance Surveillance and Target Acquisition (RSTA), Unmanned Aerial Vehicles (UAVs),

information management, counter C4 and C4 protection, position/location and navigation, and systems engineering. Each element incorporates existing programs in the C4ISR development community as well as important new capabilities. Placing system engineering at the foundation connotes a need to orchestrate these disparate elements into a single integrated system to meet these challenging operational needs. Each of these elements is further defined and discussed in the Information Domination report.

C4ISR will play a critical role in the Objective Force and the solution will be complex and expensive. This report offers recommendations directed toward developing an integrated and robust solution.

Enabling Tactical Information Superiority

- **Locate the Enemy,**
 - Mix of Sensors
 - Report Automatically
- **Communicate,**
 - New Radios
 - Integral Routers
 - Airborne Relay
- **Synthesize Reports,**
 - Minimize clutter,
 - Highlight Threats
 - Display Relevant Real Time Tactical Information
- **Airborne, UAV, Ground Sensors, Robust GPS,**
 - SIGINT, FOPEN, MTI/SAR, Retro-Optic, etc
 - Automatic Target Detection, ATR (?)
- **Enable Real Time distribution to all users**
 - Increased Bandwidth to Handle Traffic
 - Manage Traffic flow, Minimize Latency
 - UAVs to Support Communications BLOS
- **Deliver Tailored Combat Information**
 - Flush data outside the Area of Interest,
 - Correlate like Reports, Fuze information
 - Relate to terrain, maps, DTED >4
 - Interface to the Warfighter

**Without a “System” Dedicated to the Tactical Warfighter,
the Picture Will Be Late and Incomplete!**

Information superiority for the Objective Force will be critical to its operations and will prove to be a challenge to define, develop, field and train.

The solution depends on a chain of events - all of which are critical to meeting the needs of tactical operations. Meeting the timelines inherent to the mobility of the Objective Force will require the move from the classic approach to battlefield intelligence to an automated process dedicated to the tactical force which produces *Combat Information*. Technology has advanced to the point where it is not necessary for analysts to evaluate imagery and other sensor products to produce useful information, and intelligence personnel are not required to assist in the processing of sensor data and operational reports to produce an adequate picture of the battlefield.

The process defined includes three principal capabilities: 1) The ability to find and automatically report the presence of likely / potential enemy elements; 2) The capability to route these reports over the battlefield to all warfighters in the vicinity with essentially no delay; and 3) Automated processes capable of condensing a rich and rather noisy stream of information into a coherent picture of the battlefield. The intense nature of the close battle requires information in near real time, *in seconds at most, not minutes*.

Find And Report

The problems associated with finding a dispersed enemy whose forces may wear black pajamas or who move about the AO in armed pickup trucks has faced our forces in Vietnam, Somalia and in Bosnia. The irregular nature of many threats and the unforgiving terrain in which they operate requires a rich mix of sensor capabilities.

- SIGINT systems have the capability to detect, locate to some degree, and usually identify radio and radar transmitters. The ability to detect and provide a line of bearing to a forward observer (who may be the local farmer) who is sending a spot report or calling for preplanned fires, can improve force survivability.
- FOPEN Radars have progressed to the level where they can detect and determine the overall dimensions of metallic objects in heavy foliage. They are unlikely to be able to identify these objects. This level of warning might be likened to the radar warning on an aircraft - one may do additional scouting in the area or may make the decision to avoid an unnecessary encounter.
- MTI and SAR Radars have the ability to monitor large areas for movement (MTI) and to provide day / night all weather imaging capability to "check out" suspicious entities on the battlefield.
- Retro-Optic sensors employ a low power laser to scan for optical systems that are pointed toward the sensor. When the sensor detects an optical system it can produce very accurate azimuth, elevation and range to the device.
- Automatic processing of the sensor data can convert an identified radio signal, or an image into a SALUTE like report (at this time there is an object at location x, y), in digital form, for transmission to the troops. The level of description of the target will vary from a SIGINT report that it has found a Gun-Dish radar associated with a ZSU-23 4, to a FOPEN radar which might report a tank sized blob.

Communicate the Results

To route critical information across the battlefield in near real time will require much greater bandwidth than that afforded by current radios. A wideband version of the JTRS radio will be necessary with an embedded router to support the direction of traffic to those who need it. To connect elements of a dispersed force beyond the line of sight, radio relay packages on UAVs will provide the connectivity. This communications network is an evolution of the current two-dimensional digitized battlefield into a three-d configuration.

The traffic routing on this network will rely on Internet protocols, with extensions to accommodate the fact that the entire network is moving, in contrast to the fixed infrastructure of the commercial world.

Synthesize Reports

A number of automated functions must be performed to minimize the clutter and noise presented to the warfighter,. At the combat platform level all incoming reports will screened with the following possible outcomes.

- If the event reported lies outside the operators predefined area of interest (more than 5km away) or if it is an event he has "instructed" the system to ignore, it will be discarded.
- If duplicate or repetitive reports are received they are correlated into a single record and shown as a single icon on his display. The record supporting the icon might include the fact that the

air traffic control radar at the airport has been on for the past three days, it has been collected 500 times, its location is known to cms, and it was last seen 2 seconds ago.

- Groups of reports which fit predefined "templates" might be grouped to indicate that the vehicles and radios detected are representative of a Battalion Command Post.

An operator defined composite of these reports would be displayed in a situation display, which would provide the option of showing digital terrain, rectified imagery and / or military maps. The object is to display the disposition of forces in a form that has the most meaning to the individual operator in the given situation.

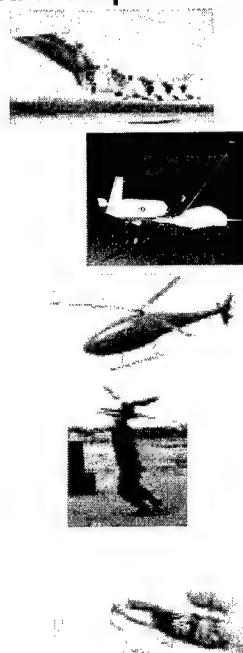
Finally and most difficult, the situation must be presented to the operator on a manner which he can rapidly assimilate, with minimal intrusion into his already complex environment. This is an area that deserves a great deal of attention.

Unmanned Aerial Vehicles

**Support continuous sensor coverage and multiple
radio relays over the AO**

Nature of the Problem

- Organic and dedicated UAVs are critical to the implementation of the Tactical InfoSphere
- COTS will provide the high altitude platforms and components for the medium altitude
- The family of UAVs will not be available for the Objective Force without strong proponency



Solutions

- Organic UAVs operating at low, medium, and high altitudes under the direct control of tactical commanders
- Focus Army S&T on cost reduction, self-protection, autonomous operation, and MEMS sensors and actuators

The dynamics and high mobility of the FCS battlefield leads to a requirement for rapid, responsive, and organic sensing and communications capability. Such a capability can only be provided by airborne platforms under the direct control of the commander. A multi-tier family of unmanned aerial vehicles (UAVs) is therefore a critical enabling technology that must be considered for the objective force. This suite of UAVs is expected to be organic to the commander at the Brigade level (Bde) and at echelons below.

UAVs fall into three operating zones: high flyers with the capability to fly autonomously at 55,000 ft or beyond; medium altitude flyers typically considered tactical UAVs operating in the 5,000 -15,000 ft altitudes; and low flyers in the 0 to 5,000 ft regimes.

Examples of high flyers are the USAF Global Hawk and the HELIOS electric powered platform. HELIOS is under development by AeroVironment Inc., with sponsorship from NASA. The high flyers will have the capability to self deploy and support multiple functions within the context of C4ISR. Examples of this organic battlefield support are over the horizon communication, area sensing and staring, and satellite link. The high flyer UAVs will likely be joint assets linking information to multiple units on the battlefield.

The mid-tier UAVs operate up to 15,000 ft and Predator is the best known example. Another UAV under development by DARPA is the long endurance Hummingbird A-160. The Hummingbird has a range of 4,800 Km, as a goal, with on station endurance in excess of 40 hrs. A medium altitude platform can provide over the horizon sensing, but will also be able to focus its field of regard much more precisely on valuable targets than a high flyer UAV. On the other hand, the high flyer UAV will be able to search a much larger field of regard and be more useful as a theater asset.

Both the high and mid altitude UAVs can have sufficient mission duration to permit the platforms to be staged from bases outside the area of conflict. This mode of operation would allow long duration, dedicated support to a tactical commander with no burden to the deployed unit. One might even consider contract support for this "sky hook."

Finally, the lowest tier of UAVs is the Micro Air Vehicles (MAVs). These platforms typically operate at altitudes measured in feet. They would be carried and launched by a company and scout platoon. The troops can afford to lose several of them in battle due to their expendable design. Most of this development effort is under the auspices of DARPA. They will be able to be used in both defense and offense tactics. In a defensive mode, the Micro UAVs will focus reconnaissance and surveillance over a much smaller region than either the medium or high flyers, but at a much lower latency providing information to the tactical fighter. In an offensive mode, the MAVs can carry small munitions and can also serve by jamming enemy electronics.

There are other factors that the Army needs to address in order to make multi-tier UAVs operational. The need for miniaturized ISR payloads is paramount to allow fielding significant capability on these small platforms. The survivability of these UAVs is also a critical issue to maintain reliable C4ISR for real-time, continuous operation for the tactical echelons.

Other technology challenges are the ability to provide long endurance, at far range, under low power, and at affordable costs. Many of the technologies will be leveraged from commercial developments. The Army must accelerate its procurement cycles to be able to exploit the commercial production cycle.

The panel observes that the main impediment to the adoption of UAVs in the Army has been the lack of a focused community advocating the design and adoption of such platforms. Currently, advocacy for UAVs, especially tactical UAVs, comes from the intelligence community. As the Army transitions to the objective force, the multifunctional capability of UAVs must be recognized (including the communications and the offensive operations aspects) to enable an effective family of UAVs to be fielded. The Army does not presently have a program executive officer responsible for integrating across functions to effectively field a multi-tier set of UAVs. It is very crucial that the Army establishes an overarching office to see the development, integration, testing, and fielding of a multi-tier suite of UAVs in support of the tactical infosphere.

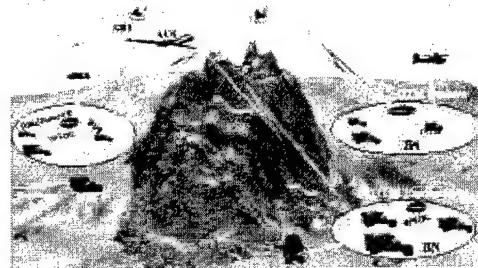
The lowest tier of UAVs will work with disposable sensors and tags as well as with robotic ground vehicles (equipped with sensors).

Communications

Fully networked, multi-layered, space, airborne, and terrestrial, compatible with the GIG

Nature of the Problem

- **The current communications network is:**
 - Line of sight, point-to-point, limited bandwidth
 - Multi-net with many interfaces
 - Modest Quality Of Service



Solutions

- **Every platform a Communications node**
- **Build on COTS technology, augmented by Army/DARPA R & D: mobile internet infrastructure, encryption,...**
- **Robust, self directing, self healing networked communications**
- **Refocus programs to support Tactical InfoSphere concept**
 - JTRS - Replacing SINCGARS, EPLRS, NTDR,
 - Redirect to meet Future Needs - Wideband/high data rate waveform
 - Fix Immature Hardware design concepts, Software constraints
 - MSE++/WIN-T- fully internet based
 - Integrate radios and routers on combat platforms and UAVs
 - Eliminate dedicated communications platforms below brigade

There are enormous challenges, and opportunities, in creating the communications system needed for the Objective Force.

In March 2000, the Deputy Secretary of Defense issued a Guidance and Policy Memo on the Global Information Grid (GIG). The memo described the GIG as “a globally interconnected, end-to-end set of information capabilities, associated processes and personnel for collecting, processing, storing, disseminating and managing information on demand to warfighters, policy makers, and support personnel.” The next generation of communications and information systems will be designed to provide military, networked capability largely based on the commercial internet. The Army challenge is to develop a mobile network, compatible with the GIG, which includes the characteristics discussed below.

Existing and programmed Army communications, although adequate at the higher echelons, are woefully antiquated and inadequate to support the Objective Force. Current Army terrestrial communications systems are limited to line-of-sight (LOS), point-to-point communication links. (SATCOM terminals have been issued to the Brigade, but operational experience shows that transponder access is rarely allocated at this level.) Furthermore, existing data radios are severely limited in bandwidth (data throughput), are stove-piped (vertically integrated), are costly to maintain, and often

have prolonged latencies resulting in missed or late messages. These limitations not only constrain accurate situational awareness and command and control today, but are hardly adequate for the additional demands of the Objective Force, such as near-real-time-sensor to shooter communications.

The communication system needed for the Objective Force is very different. It needs to be fully networked and multi-layered. The networks for this communications system will be self-directing (ad hoc) and self-healing. It must provide sufficient, flexible, scalable bandwidth (data throughput) to support the information flow within the tactical AOR as well as having the reachback capability for the support of functions such as sustainment and intelligence. By being compatible with the GIG, issues of Joint and Coalition interoperability, if not completely solved, become workable. Future JTRS radios for this system should be designed as follows: (1) built in network management, (2) IP network compatible, (3) wider in bandwidth (data throughput), (4) low probability of intercept and detect (LPI/LPD) waveforms, and (5) capability to maximize and adapt spectral efficiency for any geographical region.

Commercial telecommunications technologies will provide the core technologies, but must be integrated with Army/DARPA technologies and engineered to service the Tactical InfoSphere. There are enormous challenges, and opportunities, in creating the information system needed for the Objective Force.

Position/Navigation/Time

GPS Precision Pos/Nav/Time is THE enabler for precision targeting, coordinated maneuver and secure communications

Nature of the problem

- **GPS is deficient in:**
 - Robustness - vulnerability to enemy jamming, exploitation
 - Performance - limited coverage in complex terrain
 - System integrity - upgraded constellation IOC 2015, FOC in 2017
- **The Army owns 86% of DoD GPS receivers**
- **DoD no longer has control of GPS program**

Solution

- **Consolidate Army Pos/Nav Time activity to focus on the Objective Force**
- **Expand Army Battlespace Tactical Navigation program**
 - Augment current GPS constellation with Psuedolites
 - Develop GPS receiver and antennas to enhance anti-jam performance
 - Develop MEMS inertial systems to augment GPS
 - Transition DARPA GPS psuedolite technology to Army
 - Establish an operational capability

Precision positioning/navigation/time (Pos/Nav/Time) is critical to all dimensions of ground combat. This includes coordinating maneuver (e.g., supporting the ability to navigate over featureless terrain), precise targeting (e.g., supporting the use of guided weapons, in all weather conditions, day or night), precision attack (e.g., maximizing effect and minimizing collateral damage), and enhancing secure communications (e.g., providing the basis for rapidly synchronizing encrypted communications; supporting higher speed services needed for network operations on the battlefield). From a broader, national security perspective, precision Pos/Nav/Time is becoming the enabler for the critical infrastructures that support society (e.g., aviation, energy, finance, civil communications) as well as the host nations' infrastructure upon whose support the Army depends in the theater.

This Pos/Nav/Time capability is provided by a system-of-systems. The core of the systems mix is GPS. It provides global Pos/Nav/Time service that is seamless, consistent, and uniform, as well as a precise global timing/synchronization standard. [a brief description of GPS' technical and performance features is provided in an appendix to the Information Dominance Report]. To highlight the importance of precision Pos/Nav/Time to the Army, note that it owns 86% of the DoD user equipment requirements

for GPS [see the appendix for a break-down of this requirement across organization and requirement type].

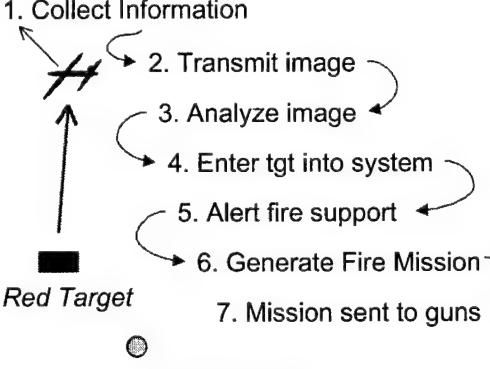
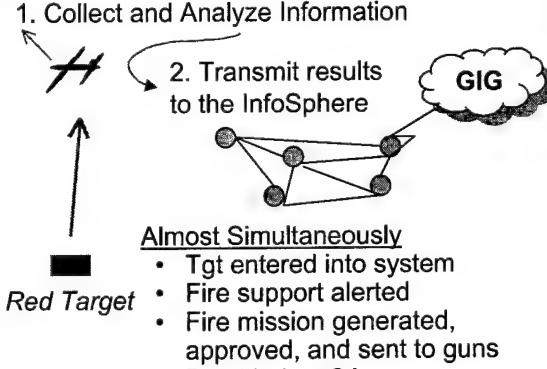
However, there are a number of areas in which GPS does not fully satisfy the Army's Pos/Nav/Time requirement. First, GPS has significant limitations in robustness. It is extremely vulnerable to adversary efforts to jam the system and to employ the system to satisfy their own needs for precision Pos/Nav/Time. Second, the performance of GPS is limited in many types of complex terrain in which the Army is expected to operate (e.g., in urban canyons; in regions featuring forests or jungles). Third, the GPS satellite constellation is currently in a fragile state (i.e., greater than 60% of the on-orbit satellites have single-string failure mechanisms). Although an extensive number of replenishment satellites are available, future high powered replacements with less jammable signals will not begin to be deployed until 2009, with FOC achieved in 2017. Finally, it must be emphasized that DoD no longer has sole control of GPS. There has long been tension between the military and civilian users of GPS in the area of exclusivity vice availability. On 2 May 2000, the tension was resolved in favor of the civil aviation community's demand for availability when the Selective Availability feature (which systematically degraded the accuracy of the signal available to the civilian community) was turned off.

There are several potential actions that the Army should pursue in the near- and mid-term, in conjunction with the other Services, to ameliorate the major deficiencies in GPS cited above. First, to enhance resistance to enemy jamming, several technologies are available to upgrade GPS user receivers and antennas. Pseudolites—pseudo satellites which are smart repeaters are an example. These pseudolites would transmit higher power signals that are less susceptible to jamming, and could add selective availability to the theater of combat to degrade an adversary's use of GPS. Second, to enhance resistance to enemy jamming, several technologies are available to upgrade GPS user receivers and antennas. These technologies, which are laid out in the Information Dominance Report, should be applied to Army combat platforms. Finally, to mitigate selected coverage and performance issues, a variety of complementary navigation systems could be developed and deployed (e.g., inertial systems employing micro-electromechanical systems (MEMS); time of arrival (TOA) processing in future communications systems such as the Joint Tactical Radio System (JTRS)). These options are discussed in Appendix H of the Information Dominance Report.

As a consequence of the analyses performed by the panel, the following major recommendations are offered. First, it is recommended that the Army's Battlespace Tactical Navigation Program be accelerated and expanded. In particular, this program should be the vehicle to transition DARPA GPS pseudolite technology to the Army and to develop MEMS inertials. Second, the panel observed that the Army's Pos/Nav/Time activities are too diffuse. To create the needed critical mass, it is recommended that the Army create a Pos/Nav/Time Center to centralize its RDT&E activities.

GPS is a Joint Problem! It has become the ubiquitous means of navigating on the modern battlefield and as such it is critical to all US forces and to our allies. This issue must be raised in the Joint arena and a common solution developed to ensure reliable support to future US warfighting missions.

Legacy Systems vs. InfoSphere

<u>Legacy (FXX)</u>	<u>Future (InfoSphere)</u>
<ul style="list-style-type: none"> • Some networked, many point-to-point communication; limited GIG access • MSE & SINCGARS limit bandwidth; MSE fixed site and vulnerable • Stovepiped, vulnerable databases • Human intensive analysis and data transfer 	<ul style="list-style-type: none"> • Fully networked communications with GIG access at the lowest tactical levels • Wider bandwidth, robust, self-organizing, self-healing communication architecture • Integrated, distributed, virtual database • Computer intensive, smart routers and multi-level security protocols
<p>1. Collect Information</p>  <p>Red Target</p> <p>Friendly Unit</p>	<p>1. Collect and Analyze Information</p>  <p>Red Target</p> <p>GIG</p> <p><u>Almost Simultaneously</u></p> <ul style="list-style-type: none"> • Tgt entered into system • Fire support alerted • Fire mission generated, approved, and sent to guns • Provided as SA

As an example of how current and future capabilities could differ, compare the operation of the current ABCS system with the potential of the future Tactical InfoSphere.

The current system is human intensive for both analysis and information transfer. An Imagery analyst visually scans imagery and identifies potential targets. He or she must then manually enter the target data in a machine readable form for transmission to AFATADS. These human interactions create unacceptable delays in the targeting / situational awareness processes. Future systems must be machine-intensive; using automated analysis to detect and report potential targets. Likewise the routing of the message must be fully automated, capitalizing on the multi-routing, multi-address capabilities of the Internet.

The current system has multiple, unique, stovepiped processes which have limited interoperability from one BFA to another. Future systems must capitalize on the broadcast nature of the tactical InfoSphere to insure near real time information to all "local" warfighters. The current system makes extensive use of point-to-point communications that are minimally networked. Future systems will be totally networked, with "instant" data flow among echelons and to components over the Global Information Grid.

The current targeting process begins with manual analysis, data input and relay through multiple OPFACs. This results in sensor to shooter time lines on the order of 5 to 10 minutes. Within the Tactical InfoSphere it should be possible to automatically detect a target onboard the UAV, generate a SALUTE like, machine readable message, and route that report to: multiple fire units, a fires decision point if needed, and to all combat units in the vicinity as a situational awareness report. With current technology there is no reason to believe the process should be longer than 5 seconds - sensor to shooter and to all local war fighters.

Three additional issues are addressed at this point in discussing comparisons and differences. They are

- a) the need for a C4ISR systems engineer and an adequate supporting organization
- b) the need for an independent Red Team
- c) substantially improved C4ISR modeling, simulation/emulation tools

The centrality of C4ISR demands that the systems engineer and the Red Team report to the Army acquisition executive. The need for modeling, simulation, and tools must be satisfied now by STRICOM and TRADOC (CONOPS and training) and CECOM (technology).

Technology Assessment to Support Objective Force Capabilities

Core Capability	Technology	EMD Risk (Tech Readiness Level ≥7 at FY2006)		
		Required	Technology	Programmatics
Info Mgmt	Intelligent Data Mgmt	<input checked="" type="checkbox"/>	Green	Yellow
	Common Operating Picture	<input checked="" type="checkbox"/>	Yellow	Yellow
	Human Machine Interface	<input checked="" type="checkbox"/>	Yellow	Red
Comm	Secure Mobile Networks	<input checked="" type="checkbox"/>	Green	Yellow
	Radios (DSP, waveforms, networks, etc.)	<input checked="" type="checkbox"/>	Yellow	Red
RSTA	EO, IR, Radar, RF, LIDAR Sensors	<input checked="" type="checkbox"/>	Green	Yellow
	Micro-acoustic, seismic, etc. Sensors	<input checked="" type="checkbox"/>	Green	Yellow
	Sensor Fusion – deconflict, Template	<input checked="" type="checkbox"/>	Green	Red
	Multi Sensor Fusion		Red	Red
	ATR-Detection and Recognition	<input checked="" type="checkbox"/>	Yellow	Red
UAV	Long Endurance	<input checked="" type="checkbox"/>	Green	Red
	Medium Endurance		Green	Yellow
	Mini/Micro		Yellow	Red
Pos/Nav	Receivers	<input checked="" type="checkbox"/>	Yellow	Red
	Antennas	<input checked="" type="checkbox"/>	Yellow	Red
	Pseudolites	<input checked="" type="checkbox"/>	Green	Red
Counter & Protect	Counterspace		Yellow	Red
	Information Assurance	<input checked="" type="checkbox"/>	Yellow	Yellow
	Sensor CM (RSTA)	<input checked="" type="checkbox"/>	Green	Yellow
	Offensive I.O.	<input checked="" type="checkbox"/>	Yellow	Red
RDA	Modeling, Simulation and Test Beds	<input checked="" type="checkbox"/>	Yellow	Red

This chart summarizes the Information Dominance Panel's assessment of the C4ISR technology availability to support objective force capabilities to the level where EMD could commence in 2006. The required column identifies technologies that the panel deemed essential to the objective force.⁴

The "technology" column contains an assessment of the technical risk for the technology. The "Programmatics" column identifies the program (current schedule and funding) risk assuming an EMD start of 2006. Technology risk categories are green—low, yellow—moderate, and red—high. Note the total lack of "green" in the programmatic column—an indication that the panel believes current schedule and funding is inadequate. At the same time, note that the initial technological capability is more than half "green" with the remainder "yellow". The challenge for the Army is setting and executing against priorities.

⁴ The details of this evaluation are included in Appendix K of the Information Dominance Report.

Support & Sustainment Panel

Feasibility of FCS Force-Level Logistics Goals

<u>Metric</u>	<u>Heavy Brigade</u>	<u>FCS Force</u>	<u>Advantage</u>
Airlift			
– Shipping Weight	24,000 STONs	6,000 STONs	75% Reduction
– Passenger Transfer	5,000 people	2,500 people	50% Reduction
Combat Power Distribution			
– Combat Vehicles	162	216	33% Greater Dispersal
– Weight of Vehicles	8,400 STONs	4,300 STONs	50% Reduction
Combat Support Equipment			
– Weight of Vehicles	15,600 STONs	1,700 STONs	90% Reduction
Daily Resupply	650 STONs	150 STONs	80% Reduction
FCS Force will provide greater lethality than current heavy brigade force and require			
– One fourth the lift footprint		- $\frac{1}{2}$ Fuel savings from Hybrid-Electric Propulsion	
– Half the soldiers and		- H2O from diesel exhaust meets $\frac{1}{2}$ the demand	
– Half the tonnage in combt vehicles.		- Precision munitions saves 50% in weight	

The support and sustainment panel created this chart to compare a heavy brigade and the FCS Force in terms of airlift, combat power distribution, combat support equipment, and daily resupply. Note the final column that shows a significant reduction in each area. The 80 percent reduction in daily resupply is accomplished by halving the number of soldiers, the weight of combat vehicles, and the number of gallons of both fuel and water.

Fuel, Power, and Propulsion Economies Can Reduce Vehicle Weight, Save Fuel

- **Discussion:**
 - Reduced vehicle weight -- the FCS should be about 25% of the M1A2
 - Hybrid-electric systems 25-50% more fuel-efficient than mechanical drives
 - The Army can capitalize on auto industry investments in the \$Bs, in hybrid-electric technology, but must tailor the technology and meet Army battlefield requirements
 - Hybrid-electric engines also meet requirements for electric power, thus allowing elimination of generators and disposable batteries
 - Fuel cell technology can potentially add to the benefits of hybrid-electric engines, but converting diesel fuel to hydrogen is a challenge today
- **Recommendations:**
 - Drive FCS development toward hybrid-electric power and propulsion systems - *focus diesel engine development on increasing the specific power and horsepower/weight ratio of commercial diesel engines as the prime power source for the hybrid power and propulsion system*
 - Evaluate cost/benefits of fuel cell technology assuming diesel fuel as the energy source and focus S&T accordingly

Fuel cells are an emerging technology that, if successful, would improve performance and could be used to upgrade (P3I) diesel electric hybrid power systems for future combat vehicles. Fuel cells generate electricity from an electrochemical reaction, but unlike batteries, they are continuously fed fuel--such as hydrogen. Fuel cells would replace the diesel-generator in a hybrid system, providing improved fuel efficiency and continuous silent operation. Because fuel cells generate electricity, they must be coupled to an electric drive for propulsion. They are between 20% and 40% more efficient than diesels. However, they are currently much larger than diesels, presenting a significant challenge for integration into a combat vehicle. Diesel hybrid electric propulsion will be available for a 2006 EMD start. Repackaging commercial diesel powerplants, not new developments, should be the path of choice. Fuel cells, which may be more efficient, will come later.

Because of the power density issue, the best near-term application for fuel cells on the battlefield is to provide high efficiency, quiet stationary power. The key technical issue with fuel cells for Army applications is how to supply hydrogen fuel for the fuel cell. Reforming diesel fuel to make hydrogen in a compact system is a challenging, DoD-specific need. Commercial systems reform methanol and

developmental work is underway to reform gasoline. However, diesel fuel is significantly more difficult to reform because of high sulfur content and there is limited developmental work on diesel reformers. One can either attempt to reform the diesel onboard the vehicle or have stationary reformers generate hydrogen, which is then stored in containers and supplied to the vehicle. Hydrogen storage is much less energy-dense than diesel fuel.

Another power application for fuel cells is soldier systems. Because of the limited quantities of fuel required for soldier systems power, it is suggested that either methanol or hydrogen fuel could be used and supplied as a packaged item. Because the energy density of fuel is much higher than the energy density of batteries, fuel cells offer longer operating times. Logistics and safety issues must be addressed.

A technology with significant long-term potential to meet Army electric power needs is a combined cycle solid oxide fuel cell (SOFC). Combined cycle, SOFC address key issues for Army applications of fuel cells, including heat rejection and utilizing diesel fuel. However, the technology is immature and will take years to develop and demonstrate.

Water Resupply Is Large Logistics Burden

- Water constitutes 40% of the daily STONS supplied for the IBCT
- By 2025 48 countries will face a shortage of fresh water
- Current potable water capabilities focus on distillation, bottled water, and water tanker trucks
- DARPA/TARDEC are demonstrating a range of revolutionary technologies for water generation and purification
- Extracting water from diesel exhaust is a promising approach
 - Combustion of one lb of fuel can yield 1.4 lbs of water (90% efficiency demonstrated, <1% reduction in engine efficiency)
- Incorporating this capability into FCS size platforms is a challenging engineering issue, as is suitable operation in weather extremes
- Recommendation: Emphasize and support the development of water self-generation as a critical area

Water is a major factor in resupply on the battlefield. With today's force, it is about 20% of the tonnage of supplies. But with fuel efficiencies and other measures to conserve materiel, water could be in excess of 40% of total tonnage in the future.

DARPA and TACOM are pursuing technologies that can generate pure water on the battlefield, while units are operating. This has the potential not only to reduce resupply requirements but to give strategic and tactical advantages to our forces.

The R&D program for water purification technology, if successful, will lead to individual small unit or vehicle-mounted water purifiers and generators. The objectives are to reduce operating and support costs, reduce the amount of man-portable equipment, and improve the deployability and sustainability of the FCS force.

One promising new technology-- the one furthest along in the R&D cycle-- generates water out of the fuel exhaust from diesel engines. The theoretical maximum is 1.4 lbs. water for each gallon of diesel fuel burned. Filters and treatment of the water would remove impurities.

There are a number of questions, including the effect on engine performance, the size and weight of the system, and the potability of the resulting water product.

A proof of concept has been completed and a prototype initiated.

On board water recovery--The proof of concept results were quite interesting. The test achieved more than one lb. of water per lb. of fuel. The resulting water met the medical standard and was better than drinking water in certain communities. Some areas need improvement in removing inorganic compounds.

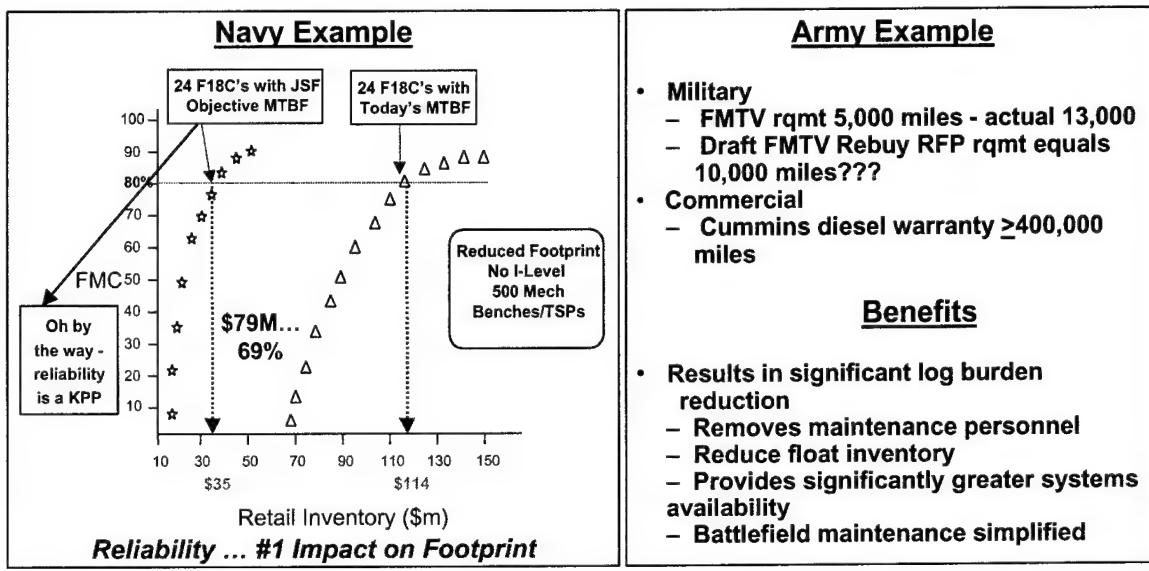
When tested on the HMMWV, there was only a 1% reduction in engine efficiency. The results to date show the potential for eliminating resupply of water on the battlefield.

We can foresee three issues. To take advantage of the technology in combat units, it should be incorporated into the FCS design. The design will be subject to tradeoffs along many dimensions to achieve its weight targets. Water generation offers a potential weight saving, if it results in less water being carried by the force to support the soldiers.

Third, DARPA and TACOM are exploring other technologies with the potential to generate pure water on the battlefield.

This is a promising area with major benefits for the support and sustainment of the FCS force.

Improving Reliability Significantly Reduces the Logistics Requirements



On the left side of this chart is a Navy example that shows the estimated effects of improving the reliability of the F18C when using the objective mean time between failures (MTBF) for the Joint Strike Fighter (JSF). On the horizontal axis is the amount of money invested in inventory to support 24 aircraft. On the vertical axis is the fully mission capable rate (FMC). The goal is to have all planes FMC 80% of the time. With today's MTBF, it is estimated that an inventory of \$114M is required to achieve an 80% FMC rate. With improved reliability that investment decreases to \$35M—a 69 percent decrease in cost. This reduction in spares inventory is accompanied by a substantial reduction in maintenance personnel footprint.

This is the kind of modeling that needs to be developed during the procurement specification period for new equipment.

The right side of the slide compares the Army's Family of Medium Tactical Vehicles (FMTV) to the commercial diesel warranty. The initial warranty for the FMTV was 5,000 miles. Actual performance shows usage on the average engine of 13,000 miles compared with the Cummins diesel warranty of over 400,000 miles. Improving reliability not only provides greater systems availability but reduces the logistics burden by decreasing the number maintenance personnel required, simplifying maintenance, and reducing the investment in inventory.

Key Support and Sustainment Recommendations

- **Establish Army Force Projection Proponent to address concepts, doctrine, and acquisition needs for projecting and sustaining early entry tactical units - make force projection an imperative**
- **Accelerate development of the hybrid-electric *power and propulsion systems* for use in FCS platforms**
- **Continue to resource DARPA/TARDEC program on converting diesel fuel exhaust to H₂O**
- **Focus medical research toward battlefield benefits from revolutionary advances in medicine**
- **Make reliability a Key Performance Parameter (KPP) to capture full potential of reliability improvements in FCS and future acquisitions**
 - Design and conduct an experiment to explore the payoff of increased reliability
- **Emphasize consistent application of planning factors based on Equipment Usage Profile (EUP) methodology**
- **Continue to tailor and apply the industry approach to Supply Chain Management**

This chart summarizes the Support and Sustainment Panel's recommendations.

Training Panel

Effective Training Makes a Difference

• Air-to-Air Combat Over Viet Nam

USN pre 1969 2:1
USAF pre 1969 2:1

Exchange Ratios:
US, primarily F-4s,
vs. MIGs

ONE
YEAR
of CTC
operation

USN 1970-73 12.5:1

Result of first use of a CTC engagement
simulation training facility (Top Gun school)

No CTC

USAF 1970-73 2:1

• National Training Center ~1987

Probability that well-trained unit *entering*
NTC wins an engagement
(arbitrary units)

TWO
WEEKS
at NTC

Change in proficiency

x30 for 237 Light Infantry Platoons

x15 58 Combined Arms Teams

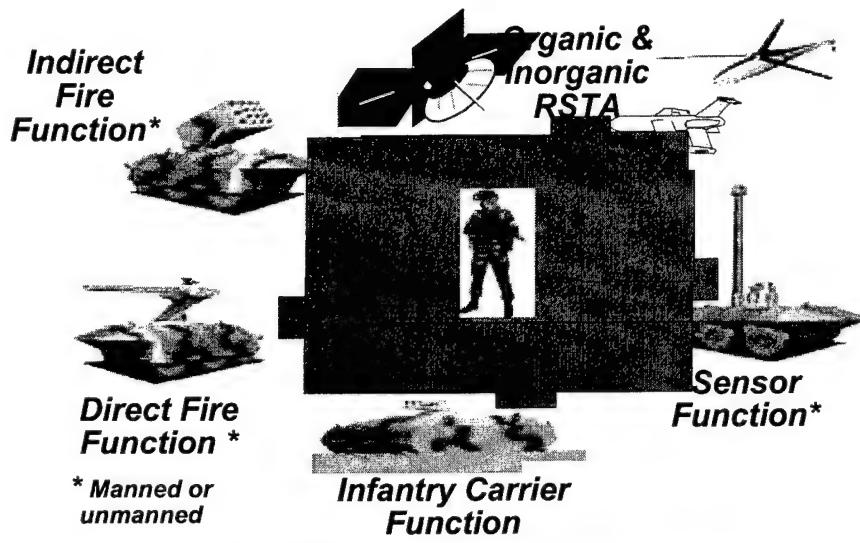
x5 428 Regiments & Brigades

Source: DSB Training Task Force on Training and Education

Information in this chart is from the Defense Science Board Task Force on Training and Education. The results of U.S. tactical engagement simulations, as measured by changed performance at the training site, are as spectacular as the Top Gun influence on air war over Viet Nam. For example, such training for ground combat increased the odds of winning an offensive mission by 30:1 for light infantry platoons as measured over 237 trials, by 15:1 for combined arms teams as measured in 58 trials, and 5:1 for regiments or brigades (428 trials).

Gorman (1995) op. cit., Chart titled U.S. Army Tactical Engagement Simulation attributed to Dr. R.H. Sulzen, ARI, 1987

The Sensor-Decider-Shooter Concept Requires Complex Information Integration



The Sensor-Decider-Shooter concept requires complex information integration. In the slide, the soldier/leader is the focus. We view this issue as a system of systems.

It is also an example of what we have been calling a very complex task. The soldier or crew in the middle is no longer required to master a single weapon and specific target, but must deal with a whole array of both weapons and sensor capabilities at levels of abstraction that are heretofore unprecedented. Adding all these new modalities and alternatives creates training and operational requirements that grow explosively through their many combinations in complexity with each added possibility.

Sensor-to-shooter operations will become increasingly complex and will pose formidable training challenges. Extensive knowledge and substantial inferential capability are required to interpret sensor data, generate hypotheses about their meaning, and propose courses of action, particularly when multiple sensors, weapons, and tactical situations are involved. All of these tasks require deep understanding of the functional properties being sensed, the operation and limitations of sensors, and the environmental or real-world interactions that affect data observation and interpretation. Further complexity is encountered in most warfare applications as intelligent opponents seek to avoid detection, confuse identification, and

gain tactical advantage by employing intelligent countermeasures or unconventional maneuvers to make sensor employment even more difficult.

From a qualitative assessment of the objective force tasks inventory and its demands on both individual and team talents, the panel concluded that approximately fifteen percent of the tasks would be classified as very complex. The remainder of the tasks were within the bounds of today's complexity. To be ready to train soldiers to work in this new environment, the Army must start a program of research and development now. In addition, simulation is needed now to meet human capability demands. The need for simulation tools was also noted by the Information Dominance Panel.

Summary: Key Findings from Training Panel

Questions	Key Findings
<ul style="list-style-type: none">• What training challenges will the Army face in the 2015-2025 era and how can it meet them?• What are the training issues in the C4ISR area?• What are the training issues for sensor-to-shooter employment?• What are the opportunities for distance learning?• What are the opportunities for embedded training?	<ul style="list-style-type: none">• Army will need to train very complex tasks; very little research on how to do it• C4ISR training is both an enabler and the Achilles heel of FCS effectiveness• Very complex tasks need to be trained at lower echelons• DL should be “Train as you fight” for the FCS force• All FCS should have network-centric training

This slide summarizes the questions we attempted to answer and the supporting findings.

The first three questions have been touched on not only by the training panel but also by the other panels. Both the combined arms character of the lowest echelon and their organic sensors/sensor platforms demand both embedded equipment and C2 approaches as well as “fight as you train” means and methodologies. Doctrine, field operations, and the “schoolhouse” must be as one, and technology is available to underwrite it affordably.

Key Recommendations from Training Panel

- **Make FCS training a Key Performance Parameter**
- **Resource ARI/STRICOM to develop FCS R&D laboratory to promote expertise in very complex tasks**
 - New capabilities for reasoning, interpretation, problem solving, decision making
 - Training for collaborative problem solving, decision making and shared situational awareness
 - Comprehensive, performance-based training management system, including metrics and instrumentation
 - Simulation, live-training, mission planning and rehearsal capabilities to exercise range of complexity
- **Develop virtual, distributed, man-in-loop emulation**
 - Joint Army-DARPA contributions
 - Use to define requirements and evaluate alternative systems
- **Integrate FCS training into the Tactical Infosphere**
 - C4ISR as enabler
 - Networked DL for home station and deployment training

The FCS will be the cornerstone of the Army's future combat power. It is imperative that training be integrated into its development from the outset. Too often in the past, training is relegated to a future time, after development, or funds originally earmarked for training are used for development. As a consequence, training is added-on or not available when the system is fielded. Given the likely complexity of the FCS, training must have a higher priority during development, second only operational performance. This will ensure that the systems developed are trainable, with embedded, network-centric capabilities, and are able to prepare the soldier to fight from the day the first unit is equipped.

The FCS will demand that soldiers possess expertise in very complex tasks. We currently do not know enough about what the soldier will need to know, or the most effective means for training the soldier. It is imperative that the appropriate agencies be resourced to conduct this research and we recommend the Army Research Institute and STRICOM. Example of the kinds of R&D needed are:

(1) We will need to obtain (recruit) or develop (train) smarter soldiers, i.e., we need new capabilities for training, reasoning, interpretation, problem solving, and decision making. What are the most effective means for doing this?

(2) We need new strategies and techniques for training across wide distances and varying skill levels and equipment. Training systems will also need to support collaboration in problem solving and

development of shared situational awareness between nodes on the FCS network. Networked distance learning capabilities need to be exploited.

(3) We need a comprehensive training management system with appropriate metrics and instrumentation. What should be in this system? How is data captured? These are the kinds of questions that need to be answered.

(4) The FCS will have many capabilities and will be responsive to multiple missions across wide distances. Learning to train with an integrated exercise of simulated and live forces and equipment, including mission planning and rehearsal capabilities, is a very complex task in itself. How should these capabilities be best captured to achieve a broad mission?

Agenda

- **Background on ASB study**
- **Desired future Army capabilities and Army modernization**
- **Panel reports**
 - **Summary**

This last section will attempt to integrate insights from the four panel reports.

Key Technology Building Blocks for Core Elements

- **Tactical infosphere**
 - VTOL-UAV platforms (long and short endurances)
 - All-weather wide area sensors
 - Active and passive high resolution sensors
 - Airborne communications relays
 - C2 information management and decision aids
 - Precise positioning and navigation systems
- **20-Ton multipurpose platforms**
 - Advanced armors and Active Protection Systems (APS)
 - Diesel hybrid electric propulsion
 - Gun (Electro-Thermal Chemical (ETC))
 - Extended range munitions and missiles
 - High reliability, prognostics and diagnostics
- **Net fires**
 - Precision Attack Missiles (PAM)
- **Follower robots (or even manned vehicles initially)**
 - Carry net fires
 - Other support functions
- **Embedded and networked training capability**
 - Supports distance learning for FCS home station and deployment training

**These
technologies
will greatly
benefit the
entire Army**

It is the Army Science Board's recommendation that the Army should start the development program with a set of technology building blocks for the core elements of the objective force. As is always the case other technologies and blocks will be added when available. These technology building blocks are largely available for a 2006 EMD start. The set involves the following things: a tactical infosphere, a 20-ton multipurpose platform, net fires, follower robots (the simplest kind), and embedded and network-centric training. The infosphere will probably have unmanned, vertical, takeoff and landing platforms because they can stare and perch, two things that fly-through sensors cannot do. They would be endowed with active and all-weather passive wide area and high-resolution sensors. These platforms will need active protection. There might be as many as three layers of them to support the echelons within the brigade. At least that is our speculation at this point. A more detailed analysis and design might confirm this analysis.

Communications relays would be mounted on the platforms, and there would be distributed information management and decision aids, all of which acting together, technically and with humans,

would provide a tactical infosphere that achieves the necessary timelines. These timelines, however, may vary from one circumstance to another.

This 20-ton multipurpose platform—there are several varieties—would have active protection, the capabilities of which would grow with time; the hybrid-electric propulsion, which has several advantages; ETC guns (electro thermal chemical guns); and extended range munitions and missiles.

The net fires would start with a precision attack missile and would subsequently incorporate a loitering attack missile. This is a starting core building block. Follower robots actually could be not only emulated but provided in the force by manned vehicles initially because they support vehicles, carry net fires, and perform other support functions. Network-centric training is required to do all this. Other technologies carry us beyond this, but this core of building blocks is judged by ASB to be an appropriate and a very useful starting point that will give the Army substantial capabilities.

With these core elements, the Army should be able to mass effects without physically massing whole forces as it must for the most part today. With collaborative network enablement, it should have the ability to mass effects within a unit, as well as, across similar units and echelons of collections of similar units. Massing of effect could as a minimum provide:

- a) massing survivability, spatially and temporally, within a unit
- b) massing ISR across units or echelons
- c) massing fires in a similar manner
- d) massing bandwidth for critical and time urgent purposes.
- e)

Improvements will add to the list of massed effect functions and reduce their overall latency.

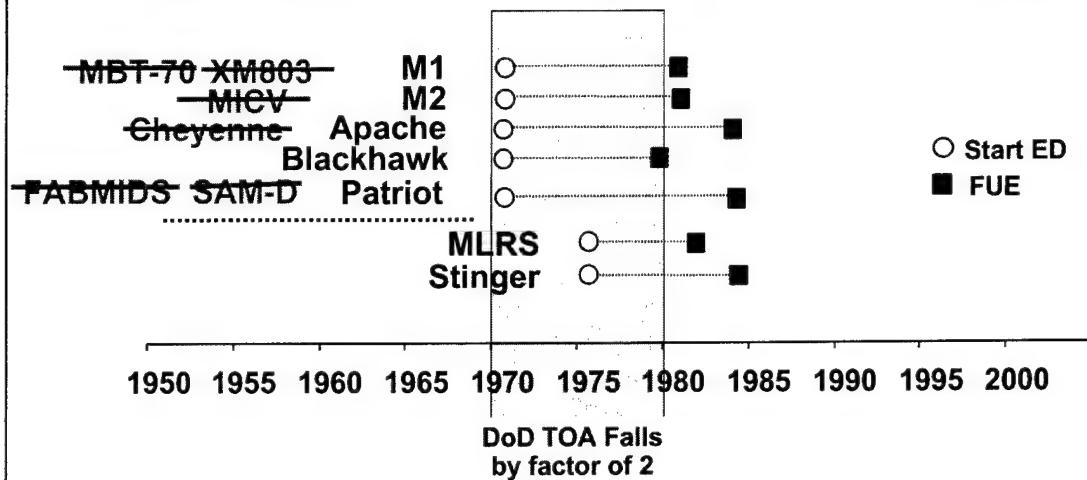
Finally, we believe that every technology enabling the objective force has great value, without exception, for the legacy force as well.

Army Modernization Has Been Difficult and Remains a Tough Job, But Can Be Successful

Enhanced Conventional Forward Defense

CONOPS: Active Defense

Big Five (Platform-centric—Acquisition Cost ~\$200B



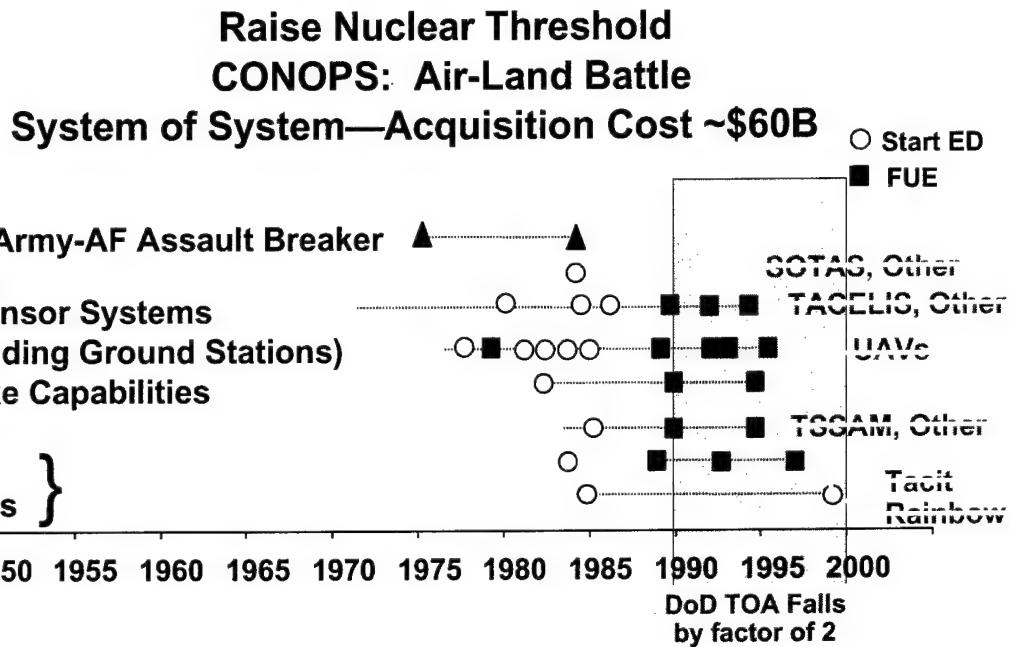
Modernization is always difficult. In the current circumstance, it is made more complex because it is part of Army Transformation. This chart and the next describe the acquisition history of some Army systems and systems of systems by way of setting the FCS and, ultimately, the objective force in context. Our overarching message is simple: modernization is difficult and requires some tough decisions. But it always has been so. However, the Army has successfully modernized itself before, and done it during periods of declining budgets.

Showed here are the Big Five systems of the Legacy Force, which, by the way, had to be pared down from the Big 17 through an exercise of management discipline. The circles indicate the start of engineering development and the squares first unit equipped. We added on MLRS because it came in later and came out very fast and STINGER, which nearly did the same thing. Both made important contributions. When development of this set of capabilities started, we were in effect enhancing forward defense, changing from a policy of massive retaliation with nuclear weapons to flexible response. Policy drove the need for additional conventional capabilities. At the same time, the budget was falling, but we went ahead.

In order to modernize, the Army had to make difficult decisions. The left side of the chart shows the systems that were cancelled en route to achieving the Big Five. A number of programs were set aside or dropped because of deficiencies. The Army killed the MBT-70 and the XM-803, which did not yield the capabilities the Army wanted, and then it started with the M-1. Some programs had a lot of money invested in them: the CHEYENNE, a rigid-rotor, spectacular-in-many-ways helicopter, a big development program was essentially cancelled.

The Army can start to field the objective force on its stated aggressive schedule. It must reduce its development alternatives to a bare minimum to both provide priority and focus resources—its own and those of its contractors. This is particularly the case now with FTR. Should the Army and Marines agree on a tilt rotor technology, it should be possible to drop the traditional helicopter S&T program. A further saving is possible if the JROC process validates the FTR as the best choice for Joint operations and the ATT program is dropped.

**... And It Got Done Despite Having to Make Tough Decisions
... And It Got Done Despite Falling Budgets**



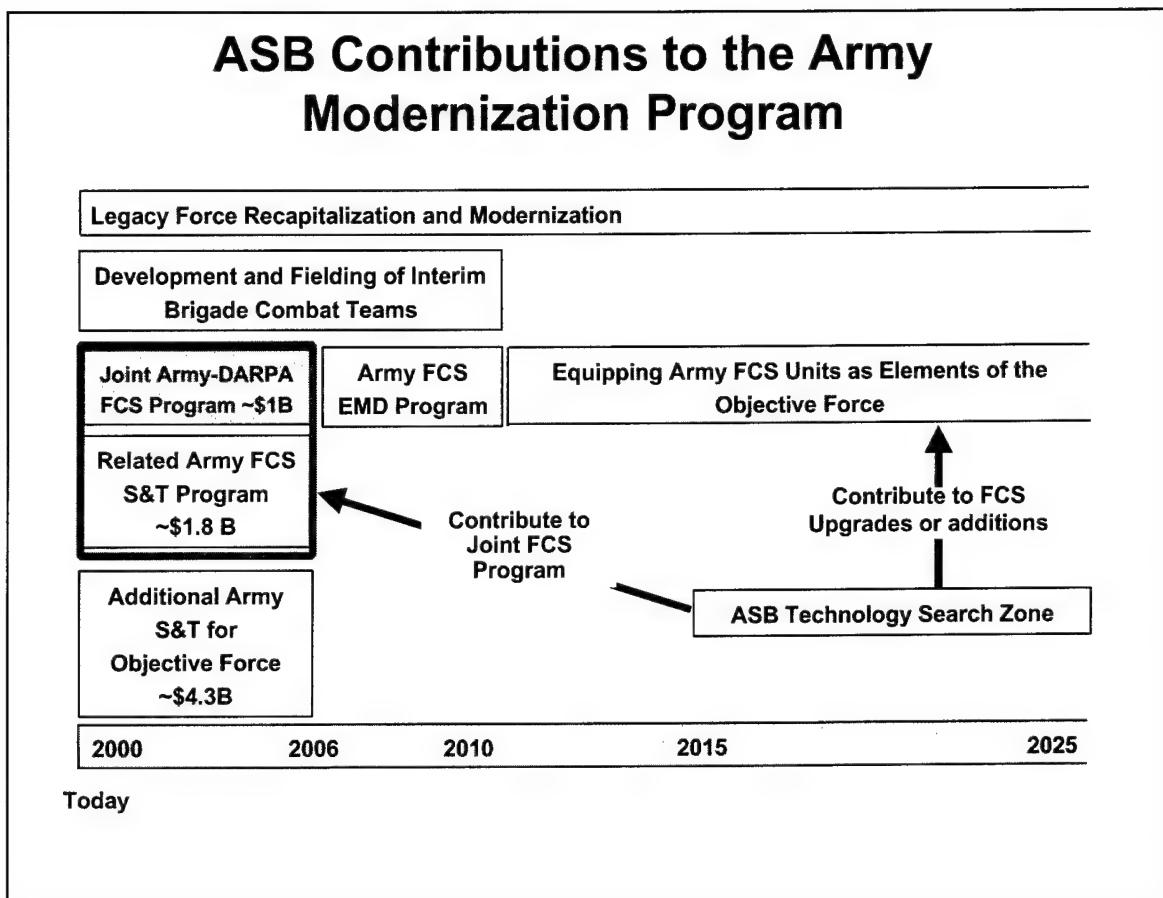
This chart shows some of the things the Army had to do to underwrite flexible response; we also had to do additional things to raise the nuclear threshold. The CONOPS for it was Air-Land battle, which evolved over time. The starter program for it was a Assault Breaker (indicated by the triangles since it did not move to the engineering development phase), interestingly enough, a DARPA-Army-Air Force program, but largely a DARPA program. It was a system of systems as contrasted to those on the first chart, which were platform centric. The budget was still falling as that program started.

On the right side of the chart are systems that were cancelled in this time period; sensors were dropped; the TSSAM (Tri-Service Stand-off Attack Missile) was dropped; TACIT RAINBOW was dropped. More importantly C4ISR was given priority because it is central to the performance of a system of systems. This is the most important lesson to take away for FCS.

The point of this somewhat extended review of history is two-fold. First, it is key to be confident about the direction. Clearly, the Army will have to make resource application decisions based upon the environment and events. Thus, understanding the vision—understanding what will get you there—is extremely important because if that is not kept in mind, it may become impossible to manage a

multifaceted program of this scope. The Army and the DoD had it clearly in mind with enhancing conventional forward defense and raising the nuclear threshold. This group of drum beaters and storytellers believes that the Army has the right vision and enough building blocks to start with. Second, history demonstrates that the nay-sayers who argue that programs of this sweep and scope cannot be accomplished in a time of diminishing budgets are wrong.

ASB Contributions to the Army Modernization Program



Big initiatives like the FCS are tough to do. They require good technology, but, more importantly, they need a vision and good management to succeed. The Army leadership has embarked on a three thrust transformation-modernization program to provide needed near and future national joint capabilities. It is creating options for future leaders. In the next few years, the shape of future capabilities will emerge. Choices made in the 2005 through 2015 will shape the Army for the next two decades.

Recommendations to Help Ensure the Early Success of the Joint Army-DARPA FCS Program

Implementors	Recommendations	
VCSA with AAE, CGs TRADOC and AMC, Director of DARPA	Conduct frequent technology reviews to ensure continuing success	<ul style="list-style-type: none"> • Tenaciously support core elements • Use operational/ technical metrics as programs mature • Kill substandard programs
CGs TRADOC and AMC (STRICOM)	Develop initial virtual, distributed, man-in-loop emulation/simulation now	<ul style="list-style-type: none"> • Use as joint program design and trade-off tool for government and contractor teams • Use as C4ISR/training system multipurpose emulation/simulation tool
AAE	Establish a FCS C4ISR system architect / system engineer, and a "red team" now, both under the AAE	<ul style="list-style-type: none"> • Formulate/integrate C4ISR building blocks for FCS • Develop interface specifications and flow-down requirements • Ensure support for embedded home station training and deployment • Red Team challenges design and stresses system during tests and experiments
VCSA and AAE, with CGs TRADOC and AMC	Create an integrating/ proponency mechanism to address FTR now	<ul style="list-style-type: none"> • Formulate joint enterprise with Marines, Air Force, NASA, DARPA, and industry • Stimulate/conduct JWCAs and JROCs with CINCs, JCS, and enterprise partners • Ensure FTR requirements and R&D remain consistent with other objective force needs

Our wrap-up recommendations start with the earlier explanation of the joint DARPA-Army program and its complementary and contributing Army S&T programs.

The first is that there must be frequent, high-level reviews that address the core and the building blocks, and that the participants actually carry out, when necessary, the infanticide of young programs that are not delivering the desired capabilities or are tangential to the vision. How frequent? More often than yearly. Back in Assault Breaker and Big Five days, some of these reviews occurred every six to eight weeks to make sure the program got off the ground right. We have identified this group of people listed on the chart as the possible implementers of those reviews, including the director of DARPA.

Next, we have mentioned the need for an emulation simulation and having it soon for a variety of purposes. The current simulations were what was needed for the platform-centric and the attrition-based system of systems. They worked well for that purpose, but they are not adequate for what has to be done now in the time available to do it. This does not mean we should jettison what we have now. Rather, we have to complement it with distributed man-in-the-loop emulation simulation. In this arena, the Army is

the world's expert. It is a matter of putting it together with the building blocks currently available, and it will help everything: this program, the training subsystem, and acquisition program decision making.

The third point pertains to tactical infosphere, establishing an architect, engineer and red team. Since it is an acquisition matter, the AAE should take on that task.

The final point addresses getting an FTR launched correctly (i.e., getting the enterprise going and enlisting the necessary support). The first and most important activity must involve the most senior Army and Marine Corps leadership in establishing a real program with real requirements. A continuing and seriously supported joint activity must be created. Along with that the FTR must be considered and accorded attention for what it is—part of a revolutionary, multifaceted power projection and sustainment Joint Force capability, not just a heavy lift helicopter.

Recommendations That Can Help Ensure a Full-Capability FCS Is Successfully Developed and Fielded

Secretary and Chief should consider:

- ***Having one message for many messengers***
- ***Creating a super program***
 - *Establishing a super systems engineer is required*
- ***Creating a long-term, expanded relationship with DARPA***

Finally, we have three suggestions for the Secretary and the Chief to consider: The vision really has to be promulgated in the same way by all the messengers who go out with it. There can only be one message. The Army will have to have many messengers dealing with a variety of communities, even during the tenure of one Secretary and one Chief. In addition, this modernization is going to be a four or five leadership generation process.

Secondly, consider forming a super program as things move downstream and understanding how the building blocks and the core elements are going to come together.

The third thing is that the Army can get this moving at the fastest possible pace with DARPA for a variety of reasons, both technology generation and exploitation on one hand, and rapid contracting on the other. We recommend the Army use the FCS initiative as an opening phase of a continuing and long-term relationship with DARPA.

APPENDIX A

TERMS OF REFERENCE



REPLY TO
ATTENTION OF

DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT SECRETARY OF THE ARMY
ACQUISITION LOGISTICS AND TECHNOLOGY
103 ARMY PENTAGON
WASHINGTON DC 20310-0103

February 28, 2000

Mr. Michael J. Bayer
Chair, Army Science Board
2511 Jefferson Davis Highway, Suite 11500
Arlington, Virginia 22202

Dear Mr. Bayer:

I request that you conduct an Army Science Board (ASB) Summer Study on "Technical and Tactical Opportunities for Revolutionary Advances in Rapidly Deployable Joint Ground Forces in the 2015-2025 Era." The ASB members appointed should consider these Terms of Reference (TOR) as guidelines and may include in their discussions related issues deemed important or suggested by the sponsors. Modifications to the TOR must be coordinated with the ASB office.

I envisage that this work by the Army Science Board will also yield practical near term insights and opportunities that will assist the Army Leadership in focusing priorities for our limited research, development and acquisition accounts to create the most combat effective and cost efficient rapidly deployable joint ground forces for the 2015-2025 period.

The study should be composed of four parallel investigations leading to an integrated set of recommendations. This work is to be guided by, but not limited to, the following lines of inquiry:

Team 1 - Operations. To the goal of achieving rapidly deployable forces with dominant maneuver supported by precision fires, look at those opportunities which offer the greatest pay off for quickly deploying forces which feature a highly flexible array of full spectrum force capabilities. Focus on combat operations, accounting for capabilities required to achieve systems overmatch as a critical component of overall force effectiveness both for initial entry into a theater of operations and to enable operational maneuver within the theater once operations begin. The array of systems and force capabilities should assure future commanders retain battlefield freedom of maneuver and are not denied tactical options for offensive or defensive schemes of maneuver. While combat operations are the focus, the relevance of the capabilities to stability and support operations, such as peace operations, should be assessed. Consider, but do not limit your investigation to the following opportunities:

- a. Look at the feasibility of synchronizing the requirements for the Future Combat System, the Joint Transport Rotorcraft (JTR), and Comanche to provide revolutionary tactical and theater mobility and increased strategic mobility. If feasible, what are the assumed tactical benefits of this union?
- b. Assess the capabilities gained by exploiting robotic air and ground systems as reconnaissance/surveillance, attack systems, and other functions. Which force capabilities or platforms appear to benefit most from this relationship?
- c. Propose a suite of smart munitions/sensor combinations in our direct fire and indirect fire forces that offer the most cost effective investment and the most decisive outcome in expected scenarios.
- d. Determine those areas of the force that demand robust 24 hours a day, 7 days a week manning, and portray the benefits of various manning arrangements.
- e. Identify the optimal organizational structures that best exploit future information technology.
- f. Determine the need for or utility of an Advanced Theater Transport (ATT) to replace the C-130 to support the operational capability and systems described above.

Team 2 – Sustainment and Support. To the goal of providing this force a support/sustainment capability with significantly reduced logistic burden, look at the opportunities in providing forces with significantly greater systems reliability (including mechanical, electronic, photonic reliability, etc.) along with graceful degradation and ultrareliability leading to simplified battlefield maintenance, repair and diagnostics/prognostics (including disposable/expendable components/systems), significantly smaller fuel and ammunition tonnage requirements, improved battlefield medical support, transport means (manned and unmanned), and remote services. Consider, but do not limit your investigation to the following opportunities:

- a. Assess the opportunities to leave outside the theater significant logistic, intelligence, and administrative support, thereby reducing the force requiring in-theater support.
- b. Assess the opportunities for advanced power plants that reduce the specific fuel consumption at least 25% per HP delivered.
- c. Assess the logistic implications of the alternative families of smart munitions (as generated by Team 1).

- d. Exploit the opportunity for remote surgery (telemedicine) to reduce the number of in-country specialty surgeons.
- e. Assess the capability of the JTR to contribute to rapid medical treatment and evacuation along with other joint force options.
- f. Assess the opportunities to improve the Army's capability to conduct Near Shore/Logistics-Over-the-Shore operations.

Team 3 - Information Dominance. To the goal of providing this force Information Dominance through the provisioning of an advanced "central nervous system" to meet the needs of our forces and to deny the threat force basic information needs consider at least two perspectives. First is the broad, relatively global C4ISR focus that flows vertically from the Joint Task Force down through corps and divisions (as units of employment) all the way to units of action executing their tactical operations and tasks. The second perspective includes the time sensitive information at the local level that is dependent on rapidly changing battle command and control, "around the next hill/corner" situational awareness, and the needs at the tactical maneuver/support units and teams level - platforms and organic sensors centric. This assessment should consider both of these complementary perspectives. The objective of providing maneuver units a fundamental capability to expand their engagement envelopes to include short timeline, beyond line of sight and fleeting targets may provide a catalyst for this information dominance challenge. Look at capabilities which provide digital map location and terrain elevation data to support the needs of ground maneuver commanders and precision fires employment, yield superior situational awareness of friendly and threat forces, instantaneous critical logistic asset status and location, theater missile threat detection, location and ongoing tracking of any threat weapons of mass destruction, and deny the threat forces this basic capability using both lethal and non-lethal means. Provide forces with timely, reliable information updates (unit and platform level updates) to facilitate tactical and support mission planning and rehearsal during deployment and on the move. As technology opportunities are assessed, it is essential that future forces operating in urban and complex terrain environments have robust, high confidence situation awareness, across the full spectrum of military operations. Consider, but do not limit your investigation to the following opportunities.

- a. Assess the suite of National and Theater sensors: overhead, air breathing, manned and robotic necessary to provide the desired data and information.
- b. Assess the technological opportunity to provide necessary bandwidth for data, voice, and video requirements for the force.

c. Ascertain the requirements to deny the threat the necessary voice and data information he requires to effectively employ his forces.

d. Assess the ability to link all systems through an inter-netted system of non-line-of-sight communications.

Team 4 - Training. To the goal of ensuring that these deployed forces have an organic capability to train to peak effectiveness within the theater of operations, look at opportunities for providing embedded training devices for crew, team and small unit training; the ability to deliver training into the theater using "distance learning" opportunities; the ability to provide "mission rehearsal" capabilities as required; and the ability to permit staff and command training with sensitive intelligence products. These investigations should be grounded in a vision of a future training strategy for both collective and individual training which leverages a proper mix of live, virtual and constructive training and which is supported by an information based system of systems architecture. Consider, but do not limit your investigation to the following:

a. Assess the command and control systems' ability to provide necessary alternative mission analyses and threat scenario generation using all source intelligence.

b. Assess the opportunities for embedding necessary training system requirements in the Future Army Land and Aviation Vehicles, to include mission rehearsal capabilities. This assessment should include embedded joint training and real time cooperative training with units and systems both in and out of theater from alert through deployment and employment.

c. Assess the training requirements necessary to train the sensor to shooter precision fires employment.

d. Look at the need for and feasibility of using distance learning techniques to train portions of the force with out-of-Theater resources.

e. Investigate approaches which can link training and operational system capabilities to facilitate the creation of realistic conditions and which can store, fuse, filter and disseminate relevant information to a variety of training system components.

Study Support. Sponsors of this study are GEN John M. Keane, Vice Chief of Staff; GEN John N. Abrams, Commanding General, US Army Training and Doctrine Command; GEN John G. Coburn, Commanding General, Army Materiel Command, and LTG John J. Costello, Commanding General, Space and Missile Defense

Command. LTG Paul J. Kern is the ASA(ALT) cognizant deputy and LTG Randall L. Rigby, Jr., is the TRADOC cognizant deputy.

Schedule. The study panel will initiate the study immediately and conclude its effort at the report writing session to be conducted July 17-27, 2000, at the Beckman Center on the campus of the University of California, Irvine. As a first step, the study co-chairs will submit a study plan to the sponsors and the Executive Secretary outlining the study approach and schedule. A final report will be issued to the sponsors in September 2000.

Sincerely,



Paul J. Hoeper
Assistant Secretary of the Army
(Acquisition, Logistics and Technology)

APPENDIX B

PARTICIPANTS LIST

PARTICIPANTS LIST

ARMY SCIENCE BOARD 2000 SUMMER STUDY

TECHNICAL AND TACTICAL OPPORTUNITIES FOR REVOLUTIONARY ADVANCES IN RAPIDLY DEPLOYABLE JOINT GROUND FORCES IN THE 2015-2025 ERA

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APPENDIX C

ACRONYMS

Acronyms

A2C2	Army Airspace Command and Control
AAC	Army Acquisition Corps
AAE	Army Acquisition Executive
AAFIF	Automated Air Facilities Information File
AARS	After Action Reviews
ABCS	Army Battle Command Systems
ABN	Airborne
ACAT	Acquisition Category
ACOM	Atlantic Command
ACR	Armored Cavalry Regiment
ACTD	Advanced Concept Technology Demonstration
ADO	Army Digitization Office
AEF	Air Expeditionary Force
AF	Air Force
AFSAB	Air Force Scientific Advisory Board
AFSS	Advanced Fire Support System
AJ	Anti Jamming
AGCCS	Army Global Command and Control System
AGS	Armored Gun System
AI	Artificial Intelligence
ALP	Advanced Logistics Project
AMC	Army Materiel Command
AMCOM	Aviation and Missile Command
AMSAA	Army Materiel Systems Analysis Activity
AOR	Area of Responsibility
APFSDS	Armor-Piercing, Fin-stabilized, Discarding Sabot
APC	Armored Personnel Carrier
APOD	Aerial Port of Debarkation
APOE	Aerial Port of Embarkation
APS	Active Protection Systems; Army Prepositioned Stocks
ARDEC	Army Research, Development, and Engineering Center
ARL	Army Research Laboratory
ATT	Advanced Tactical Transport
ARTY	Artillery
ASA(ALT)	Assistant Secretary of the Army for Acquisition Logistics and Technology
ASB	Army Science Board
ASD C3I or ASD(C3I)	Assistant Secretary of Defense (Command, Control, Communications, and Intelligence)
ASTMP	Army Science and Technology Master Plan
ASTWG	Army Science and Technology Working Group
AT	Anti Tank
ATD	Advanced Technology Demonstration
ATG	Anti-Tank Gun

ATGM	Anti-Tank Guided Missile
ATR	Automated Target Recognition
AWE	Advanced Warfighting Experiment
B2C2	Battalion and Below Command and Control
BAT	Brilliant Anti-Tank
BCIS	Battlefield Combat Identification System
BDA	Battle Damage Assessment
BDE	Brigade
BITS	Battlefield Information Transmission System
BLOS	Beyond Line of Sight
BN	Battalion
C2	Command and Control
C2E	Command Center Element
C2OTM	Command and Control On-The-Move
C2SID	Command and Control System Integration Directorate
C2T2	Commercial Communications Technology Testbed
C2V	Command and Control Vehicle
C2W	Command and Control Warfare
C3	Command, Control and Communications
C3I	Command, Control, Communications and Intelligence
C3IEW	Command, Control, Communications Intelligence and Electronic Warfare
C4	Command, Control, Communications and Computers
C4I	Command, Control, Communications, Computers and Intelligence
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CASCOM	Combined Arms Support Command
CASTFOREM	Combined Arms and Support Task Force Evaluation Model
CBW	Chemical and Biological Warfare
CC&D	Concealment Camouflage and Deception
CDR	Critical Design Review
CDT	Commercially Driven Technologies
CE	Chemical Energy
CECOM	Army Communication-Electronics Command
CHP	Controlled Humidity Preservation
CINC	Commander-in-Chief
CINCTRANS	Commander-in-Chief, Transportation Command
CKEM	Compact Kinetic Energy Missile
CM	Countermeasures
CONOPS	Concept of Operations
CONUS	Continental United States
COA	Course of Action
COTS	Commercial Off-The-Shelf
CPX	Command Post Exercise

CRAF	Civil Reserve Air Fleet
CSA	Chief of Staff, Army
CSSCS	Combat Service Support Computer System
CTC	Combat Training Center
DARPA	Defense Advanced Research Projects Agency
DAS	Director of Army Staff
DAS(R&T)	Deputy Assistant Secretary for Research and Technology
DBBL	Dismounted Battlespace Battle Lab
DCS(RDA)	Deputy Chief of Staff Research Development and Acquisition
DCSD	Deputy Chief of Staff Combat Development
DCSDOC	Deputy Chief of Staff Doctrine
DCSINT	Deputy Chief of Staff Intelligence
DCSLOG	Deputy Chief of Staff Logistics
DCSOPS	Deputy Chief of Staff Operations
DDR&E	Director, Defense Research and Engineering
DE	Directed Energy
DEW	Directed Energy Weapons
DISA	Defense Information Systems Agency
DISC4	Director, Information Systems, Command, Control, Communications and Computers
DL	Distance Learning
DLA	Defense Logistics Agency
DMSO	Defense Modeling and Simulation Office
DoT	Department of Transportation
DPG	Defense Planning Guide
DPICM	Dual Purpose Improved Conventional Munitions
DS	Direct Support
DSB	Defense Science Board
DSWA	Defense Special Weapons Agency
DSP	Digital Signal Processing
DTAP	Defense Technology Area Plan
DTLOMS	Doctrine, Training, Leader Development, Organization, Materiel, and Soldiers
DTO	Defense Technology Objective
DU	Depleted Uranium
DUSA-OR	Deputy Undersecretary of the Army - Operations Research
EAD	Echelons Above Division
EFOGM	Enhanced Fiber-Optic Guided Missile
EFP	Explosively Formed Penetrator
ELINT	Electronic Intelligence
EM	Electro-Mechanical, Electro-Magnetic
EMD	Engineering and Manufacturing Development
EML	Electro-Magnetic Launch
EMPRS	En Route Mission Planning and Rehearsal System

EO/IR	Electro-Optical/Infrared
ERA	Extended Range Artillery, Explosively Reactive Armor
ETC	Electro-Thermal Chemical
EW	Electronic Warfare
F&M	Firepower and Mobility
FBCB2	Force XXI Battle Command Brigade and Below
FC	Fire Control
FCS	Fire Control Systems; Future Combat System
FCV	Future Combat Vehicle
FCVT	FCV Team
FLIR	Forward Looking Infra-Red
FOB	Forward Operating Base
FOG-M	Fiber-Optic Guided Missile
FORSCOM	Forces Command
FTR	Future Transport Rotorcraft
FSCS	Future Scout and Cavalry System
FSV	Future Scout Vehicle
FTX	Field Training Exercise
GCCS	Global Command and Control System
GCSS	Global Combat Support System
GCSS-A	Global Combat Support System – Army
GIG	Global Information Grid
GIS	Global Information System
GOSC	General Officer Steering Committee
GPS	Global Positioning System
GVW	Gross Vehicle Weight
HE	High Explosive
HEAT	High Explosive Anti-Tank
HHH	Hand-Held Heat
HIMARS	High Mobility Artillery Rocket System
HMMWV	High Mobility Multi-purpose Wheeled Vehicle
HNS	Host Nation Support
HPM	High Power Microwave
HQAMC	Headquarters of the Army Materiel Command
HSS	High-Speed Shipping
HVAP	High Velocity Armor Penetrating
I2R	Imaging Infrared
IA/IW	Information Assurance/Information Warfare
ICM	Improved Capabilities Missile, Improved Capabilities Munitions
IFSAR	Interferometric Synthetic Aperture Radar
III	Integrated Information Infrastructure(s)
IO	Information Operations

IPT	Integrated Product Team
IR	Infra Red
IR&D	Independent Research and Development
ISC/R	Individual Soldier's Computer/Radio
ISR	Intelligence Surveillance Reconnaissance
IT	Information Technology
IW	Information Warfare
IWS	Individual Warfighter System
J3	Operations Directorate, Joint Staff
J4	Logistics Directorate, Joint Staff
JCF	Joint Contingency Force
JCS	Joint Chiefs of Staff
JIT	Just-in-Time
JOPES	Joint Operation Planning and Execution System
JROC	Joint Requirements Oversight Council
JS	Joint Support, Joint Staff
JSTARS	Joint Surveillance Target Attack Radar System
JTA	Joint Technology Architecture(s)
JWCA	Joint Warfighting Capability Assessment
KE	Kinetic Energy
KE/CE	Kinetic Energy / Chemical Energy
KEM	Kinetic Energy Missile
LAM	Land Attack Missile
LADAR	Laser Radar
LAV	Light Armored Vehicle
LAW	Light Anti-tank Weapon
LCLO	Low Cost Low Observable
LCMS	Laser Counter Measures System
LCPK	Low Cost Precision Kill
LIDAR	Light Detection and Ranging
LIWA	Land Information Warfare Activity
LLNL	Lawrence Livermore National Laboratory
LMSR	Large Medium Speed Roll-on/roll-off
LO	Low Observables
LOS	Line of Sight
LOSAT	Line-of-Sight Anti-Tank
LOTS	Logistics Over-the-Shore
LPD	Low Probability of Detection
LPI	Low Probability of Intercept
LRIP	Low Rate Initial Production
LTL	Less-than-Lethal
LW	Land Warrior

M&S	Modeling and Simulation
MAGTF	Marine Air-Ground Task Force
MANPADS	Man-portable Air Defense System
MANPRINT	Manpower and Personnel Integration
MAVs	Micro-Autonomous Vehicles, Micro Air Vehicles
MEM	Micro-Electro-Mechanics
MEMS	Micro Electric Mechanical System
MEP	Mobile Electric Power; Mission Equipment Package
METT-T	Mission, Enemy, Troops, Terrain, Time
MEU	Marine Expeditionary Unit
MHE	Materiel Handling Equipment
MILDEP	Military Deputy
MLRS	Multiple Launch Rocket System
MMCS	Multi-Mission Combat System
MMUAV	Multi-Mission Unmanned Air Vehicle
MNS	Mission Needs Statement
MOUT	Military Operations in Urban Terrain
MPIM	Multipurpose Infantry Munition
MPS	Maritime Prepositioning Ship
MRDEC	Missile Research, Development and Engineering Center
MSTAR	Moving and Stationary Target Acquisition and Recognition
MTI	Moving Target Indicator
MTI-SAR	Moving Target Indicator – Synthetic Aperture Radar
MTMC	Military Transportation Management Command
MTMC-TEA	Military Transportation Management Command – Transportation Engineering Agency
MVMT	Movement
MW	Mounted Warrior
NBC	Nuclear, Biological and Chemical
NDF	National Defense Features
NG APS	National Guard - Army Prepositioned Stocks
NGB	National Guard Bureau
NGIC	National Ground Intelligence Center
NL	Non-Lethal
NLT	No Later Than
NLW	Non-Lethal Weapons
NMD	National Missile Defense
NRAC	Naval Research Advisory Committee
NRDEC	Natick Research, Development and Engineering Center
NSA	National Security Agency
NTC	National Training Center
NVESD	Night-Vision/Electronic Sensors Directorate
O&O	Operational and Organizational
OCAR	Office of the Chief, Army Reserve

OCONUS	Outside Continental United States
ODCSOPS	Office of the Deputy Chief of Staff for Operations
OOTW	Operations Other Than War
OPM	Other People's Money
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
P3I	Preplanned Product Improvement
PAM	Precision Attack Munitions
PDR	Preliminary Design Review
PDRR	Program Definition/Risk Reduction
PEO	Program Executive Office (Officer)
PEO/3C	Program Executive Officer for Command, Control and Communications
PGM	Precision Guided Munitions
PGMM	Precision Guided Mortar Munitions
POD	Point of Debarkation
POL	Petroleum, Oil and Lubricants
POM	Preparation for Overseas Movement
POS/NAV	Position/Navigation
PREPO	pre-positioned stocks
RHA	Rolled Homogenous Armor
RHAE	Rolled Homogenous Armor Equivalent
R/S	Reconnaissance/Surveillance
RC	Reserve Component
RDA	Research Development and Acquisition
RDT&E	Research Development Testing and Evaluation
RFPI	Rapid Force Projection Initiative
RHA	Rolled Homogenous Armor
RORO	Roll-on Roll-off
RPG	Rocket Propelled Grenade
RRF	Rapid Reaction Forces
RSTA	Reconnaissance Surveillance, Target Acquisition
S&T	Science and Technology
SA	Situation Awareness
SAALT	Secretary of the Army for Acquisition, Logistics and Technology
SACLOS	Semi-Automated Line of Sight
SADARM	Sense and Destroy Armor
SAR	Synthetic Aperture Radar
SARDA	Secretary of the Army for Research Development and Acquisition – outdated, now SAALT – Secretary of the Army for Acquisition, Logistics and Technology
SAS	Situation Awareness System
SBIR	Small Business Innovation Research

SES	Surface Effect Ships
SIGINT	Signal Intelligence
SIMNET	Simulation Network
SINCGARS	Single Channel Ground and Airborne Radio System
SIPE	Soldier Integrated Protective Ensemble
SLAD	Survivability and Lethality Directorate
SLID	Simple Low-cost Interception Device
SM	Signature Management
SRO	Strategic Research Objective
SSCOM	Soldier Systems Command
SSTOL	Super Short Take-Off & Landing
STARCC	State Area Command
STI	Stationary Target Indicator
STO	Science and Technology Objective
STOW-E	Synthetic Theater of War-Europe
SUO	Small Unit Operations
SUOSAS	Small Unit Operations Situation Awareness System
SUSOPS	Sustained Operations
SWA	South West Asia
T&E	Test and Evaluation
TAAC	Tactical Assembly Area
TAAD	Theater Area Air Defense
TACOM	Tank Automotive and Armaments Command
TAP	Technology Area Plan
TARA	Technology Area Review and Assessment
TARDEC	Tank Automotive Research Development and Engineering Center
TDA	Table of Distribution and Allowances
TENCAP	Tactical Exploitation of National Capabilities (program)
TERM	Tank Extended Range Munitions
TES	Tactical Engagement System; Tactical Engagement Simulation
TEU	20-foot-equivalent unit
TF	Task Force
THAAD	Theater High Altitude Defense System
TOC	Tactical Operations Center
TOR	Terms of Reference
TOW	Tube-Launched, Optically Tracked, Wire Command-Linked Guided
TPFDD	time-phased forces deployment data
TRADOC	Training and Doctrine Command
TRANSCOM	Transportation Command
TTT	Tactics, Techniques, and Procedures
TWG	Technology Working Group
TWS	Thermal Weapon Sight
UAV	Unmanned Aerial Vehicles
UGS	Unattended Ground Sensors

UGV	Unmanned Ground Vehicles
UHF	Ultra-High Frequency
USMA	United States Military Academy
USMC	United States Marine Corps
UV	Ultra-Violet
UWB	Ultra-Wide Band
UXO	Unexploded Ordnance
V/STOL	Vertical or Short Take-off and Landing
VCSA	Vice Chief of Staff of the Army
VISA	Voluntary Intermodal Shipping Agreement
VSAT	Very Small Aperture Terminal
VTOL	Vertical Take-off and Landing
VTOL JTR	Vertical Take-off and Landing – Joint Tilt Rotor
WARSIM	Warfighter Simulation
WIN	Warfighter Information Network
WMD	Weapons of Mass Destruction
WRAP	Warfighting Rapid Acquisition Program

For Acronyms not found here, consult:

<http://www.adtdl.army.mil/adtl/search/acronym.htm>

or

<http://www.sew-lexicon.com/>

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